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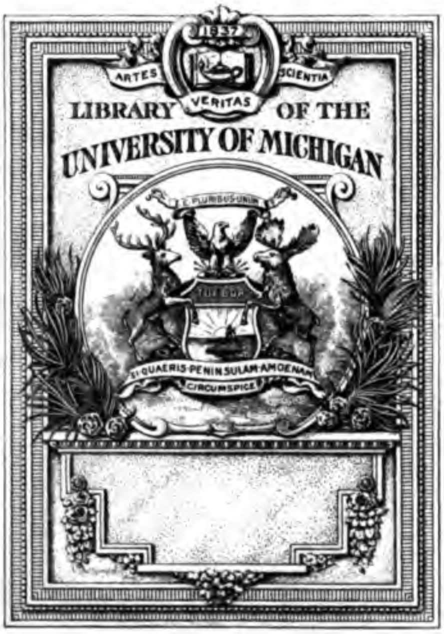
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ANNUAL REPORT

OF THE

119663

SECRETARY OF WAR

FOR

THE YEAR 1885.

IN FOUR VOLUMES.

VOLUME III.

WASHINGTON:
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1885.

REPORT

OF THE

CHIEF OF ORDNANCE.

REPORT OF THE CHIEF OF ORDNANCE.

WAR DEPARTMENT, ORDNANCE OFFICE,
Washington, October 13, 1885.

SIR: I have the honor to submit the following report of the principal operations of the Ordnance Department during the fiscal year ended June 30, 1885, with such remarks and recommendations as the interests of this branch of the military service seem to require.

The fiscal resources and expenditures of the Department during the year were as follows, viz:

Amount in the Treasury to the credit of the appropriations on June 30, 1884	$413,490 63
Amount in the Treasury not reported to the credit of the appropriations on June 30, 1884	7,545 43
Amount in Government depositories to the credit of disbursing officers and others on June 30, 1884	209,007 50
Amount of appropriations for the service of the fiscal year ended June 30, 1885	1,928,844 02
Amount refunded to ordnance appropriations in settlement of accounts during the year ended June 30, 1885	9,541 61
Gross amount received during the fiscal year ended June 30, 1885, from sales to officers; from rents; from collections from troops on account of losses of, or damage to, ordnance stores; from Chicago, Rock Island and Pacific Railroad Company; from powder and projectiles (proceeds of sales); from sales of condemned stores; from testing machine, and from all other sources not before mentioned	160,026 65
Total	2,728,455 84
Amount of expenditures during the fiscal year ended June 30, 1885, including expenses attending sales of condemned stores, powder, and projectiles, &c	1,831,674 83
Amount deposited in Treasury during the fiscal year ended June 30, 1885, as proceeds of sales of Government property	119,819 62
Amount transferred from ordnance appropriations in settlement of accounts during the fiscal year ended June 30, 1885	1,592 31
Amount turned in to the surplus fund on June 30, 1885	2,290 21
Amount in Government depositories to the credit of disbursing officers and others on June 30, 1885	233,565 74
Amount in the Treasury not reported to the credit of appropriations on June 30, 1885	6,819 21
Amount in the Treasury to the credit of appropriations on June 30, 1885	532,693 92
Total	2,728,455 84

STATIONS AND DUTIES.

The stations and duties of the officers of the Ordnance Department are as follows: Four at the Ordnance Office; thirty-nine at the arsenals, armory, and powder depots; nine on the Ordnance Board and at the foundries; six at the several military headquarters and ordnance depots; four at the Military Academy; one under the orders of the Secretary of the Interior; one in the Life-Saving Service, under the Secretary of the Treasury. To fill the vacancy caused by the death of Maj. S. C. Lyford, Second Lieut. S. E. Stuart, First United States Artillery, was transferred to the Ordnance Department, after having passed a satisfactory examination as required by law.

The Ordnance Department provides the armament for our sea-coast defenses, and arms and other ordnance stores for the Army, the militia, the Marine Corps, all other Executive Departments to protect public money and property, and the forty colleges authorized by law to receive them for instruction.

SMALL-ARMS.

During the fiscal year ended June 30, 1885, 40,657 rifles, carbines, and shotguns have been manufactured at the National Armory. Repairing arms, providing spare parts, making swords, sabers, and miscellaneous articles must be mentioned as among its operations.

The Lee, Chaffee-Reece, and Hotchkiss magazine rifles have been in the hands of troops for trial during the year, and the results, when all are received, will be specially reported on.

One thousand rod-bayonet rifles, new model, with improved sights, are also in the hands of troops for trial.

RIFLE PRACTICE.

The gold and silver medals offered as rewards for successful marksmanship in the annual department and division rifle contests have, as usual, been issued to the different headquarters in advance of the date of the contests, thus insuring their early delivery to the fortunate competitors.

During the year the bronze Marksman's pin and Sharpshooter's cross, formerly furnished the soldier as a reward for proficiency attained in practice with his company, and as a distinguishing mark of his superior skill in the use of the rifle, have been replaced with pins and badges of silver, of somewhat similar design, but much more finished workmanship. The greatly increased value which these decorations now possess in the estimation of the soldier has shown the propriety of the change.

In my last report it was stated that Capt S. E. Blunt, Ordnance Department, then chief ordnance officer and inspector of rifle practice of the Department of Dakota, was preparing, under my direction and in accordance with your authority, a new work upon target practice for the Army. Captain Blunt has since been transferred to the headquarters of the Army as inspector of rifle practice, and the new manual, after having been approved by the Secretary of War, was brought out and introduced, and is now the authorized guide for the Army. As a work upon rifle and carbine firing, both in the scientific details of the subject and in the manner in which it deals with the more practical steps of the soldier's instruction, from the unskilled recruit to the expert marksman, it seems to be all that can be desired. The skirmish firing introduced by it as an important element in determining the composition of the selected teams of marksmen, has developed in the soldier the habit of a prompt estimation of his distance from his mark and an accuracy and rapidity of fire that will very greatly increase his efficiency in battle.

The great interest taken by the Army in rifle-firing has led to an increased demand for the different materials requisite for practice, and the Department has fortunately been able to furnish liberal supplies, so that the rifle-ranges at the different posts are now better equipped than at any previous time.

THE MILITIA.

It is hardly necessary to do more than refer in a cursory way to the great need of larger appropriations for "arming and equipping the whole body of the militia," or even a reasonable fraction of it. If the General Government intends keeping the militia up to the highest practicable standard, as the main armed force of the country, then the amount deemed sufficient in 1808 must be greatly increased. If this most important duty is to be performed by the individual States, then the fact should be decided and proclaimed, that the responsibility rest upon the proper shoulders. One thing is certain, that more uniform and liberal methods and direct responsibility should be resorted to, to place on an efficient footing the militia and volunteer organizations of all the States.

And in this connection I beg leave to call attention to the absolute necessity of the proper organization of the militia force of the District of Columbia. Some of its organizations, in drill, discipline, and efficiency, are not surpassed by any in the country, and yet the armed force is divided into separate and distinct bodies without a common superior. The interests at stake in the capital of the nation call for such an armed force to be kept well in hand under one commander, ready for effective service at a moment's notice. It is not for me to decide whether the laws now in the statute book are sufficient, but the gravity of the matter seems to call for legislative and executive action.

UNITED STATES TESTING MACHINE.

The commanding officer of Watertown Arsenal has made his report of tests of iron, steel, and other materials for industrial purposes for the past fiscal year. The report will be submitted to you for transmission to Congress at the opening of the next session, as required by law.

In previous reports, the views of this office were given as to the requirements of the General Government in this regard, and the demand for additional facilities to meet the necessities of the public service and of private enterprise.

The machine cannot at present do all that is required by the public service, and series of tests, of great importance to the Government, have been and are being delayed, because the work to be done is far more than one machine can accomplish. A smaller machine, that would relieve the present one of most of the tests of small specimens, should be the first step, but the day is not far distant when the interests of the country will require still greater facilities, and in more than one locality. Larger appropriations for using the machine and providing the necessary clerical labor are absolutely essential.

BOARD ON FORTIFICATIONS OR OTHER DEFENSES.

In the last fortification bill a Board was provided for, to "examine and report at what ports fortifications or other defenses are most urgently required, the character and kind of defenses best adapted for each, with reference to armament," and "the utilization of torpedoes, mines or other defensive appliances," and the Executive order of May 12, 1885, gave effect to this legislation.

All that is needed to place our defenses in proper condition is time and money, but both time and money are vital factors. Time without money or money without time will effect nothing. It will be a costly undertaking, not to be accomplished in a year or in five, as every nation in Europe well understands from experience; but if it is to be done (and the doubters are few), the sooner we begin the better. That this Board will present a plain unvarnished statement that will carry conviction is to be expected, and it is hoped that Congress will rise to the occasion and give the necessary legislation and appropriation.

ARMAMENT OF FORTIFICATIONS.

Progress in the manufacture of the several experimental cannon, undertaken in accordance with the provisions of the act of March 3, 1883, has been so much retarded the past year that up to the date of this report only the 12-inch M. L. rifled mortar and the 12-inch B. L. rifle, cast iron, have been received at the proving ground.

The 12-inch M. L. rifled mortar was completed the last of November, 1884, and though turned over to the Quartermaster Department for transportation to Sandy Hook on December 11, 1884, it was not received at the proving ground until March 12, 1885, being three months in transit between Boston and New York. A full description of this piece, with a history of its manufacture, is contained in Appendix 25, herewith.

Experimental Firings of 12-*inch M. L. Rifled Mortar.*

From the results of the trials last year with two experimental 10-inch M. L. rifled mortars—see Appendix 17, Report of Chief of Ordnance, 1884—the Department had been led to select the Eureka sabot for the 12-inch mortar shell; and from further information gained in those trials it was enabled to determine approximately the dimensions for the sabot and the character of the powder to be used. Actual firings with the 12-inch mortar were necessary, however, to determine definitely these questions of sabot and powder. Accordingly, before turning the mortar over to the Board for Testing Rifled Cannon, appointed under the act of July 5, 1884, the Ordnance Board was directed to make some preliminary firings, with these objects in view.

Under the supervision of the Ordnance Board the mortar has been fired 44 rounds, by means of which the Board has been enabled to arrive at definite conclusions regarding the forms of sabot and natures of powder that appear suitable for the test of the piece. One form of sabot is adapted to the use of the same powder, with either full or half charges; and another form to the use of a slow powder with full charges, and a quick powder with reduced charges. The results obtained in these preliminary firings are given in Appendix 20, and from which the following is an extract:

WITH THE SAME POWDER.

Powder.		Weight of projectiles.	Velocity at 89 feet from muzzle.	Pressure per square inch of bore.
Kind.	Weight of charge.			
M. W.	*Pounds.*	*Pounds.*	*Feet.*	*Pounds.*
D. 1.725 Gr. 72	25	610	630	9,750
	48	610	970	31,500
	50	610	991	82,000
	52	610	1,017	33,750

WITH TWO POWDERS.

M. V. D. 1.700 Gr. 72	25	610	648	12,750
I. B. C. D. 1.728 Gr. 128	50	610	931	22,000

The following results also were obtained:

Powder.		Weight of projectile.	Elevation.	Range.	Time of flight.
Kind.	Charge.				
	Pounds.	*Pounds.*	*Degrees.*	*Yards.*	*Seconds.*
I. B. C. D. 1.728 Gr. 123	26	610	73	1,895	36½
M. V. D. 1.700 Gr. 72	25	610	60	4,263	33½
M. W. D. 1.725 Gr. 72	48	610	28	7,048	28

Nothing was determined as to the accuracy of fire in these preliminary trials. That is a matter to be determined by the Board for Testing Rifled Cannon who now have the mortar in hand for test, and upon whose report, in this respect, will rest largely the final determination of the question whether for sea-coast mortars, muzzle-loading, or breech. loading is the more advantageous system. The object of the Department in selecting the muzzle-loading system as the type for an experimental piece, is thus stated in the following extracts from its letter, transmitting the plan of the mortar, to the Getty Board, in April 1882:

> In working up this plan it was thought that the old method of loading from the muzzle was, on the whole, the best adapted to the purposes of a mortar.
>
> As a muzzle-loader, the piece would be somewhat lighter and considerably cheaper, and could be manufactured in much less time; and, on the other hand, no objection exists to muzzle-loading with a piece so short as a mortar, and which, at the same time, when in service, is so well protected from direct fire as to afford great freedom of movement to the cannoneers in the service of the piece.
>
> In the English service the rifled mortars are muzzle-loaders, and so, also, are the recently introduced 9.5-inch and 11.8-inch mortars in the French service. In 1874 it was, indeed, claimed in France (see Ordnance Note 68, p. 547,) that it was essential that a rifled mortar "should be loaded from the breech, in order to give the shell sufficient stability in flight, which can only be obtained in a short piece by an exact centering of the projectile—an end much less difficult of attainment with a breech-loader than with a muzzle-loader."
>
> But later, it is stated by Captain Gadaud, of the French navy (*Carnet des Notes et Renseignement*, 1881, p. 62), that, "in consequence of experiments made in 1878 with an 8.66-inch (22 centimeters) howitzer, there were adopted two mortars, of cast-iron hooped and loading at the muzzle, of 9.45-inch (24 centimeters) and 11.8-inch (30 centimeters) caliber respectively; the object had in view being the prompt procurement, and at little expense, of a great number of mortars easy to serve and not requiring the care or need of repairs that breech-loaders do."
>
> So it would appear that with the French navy, at least, it was thought that the gain in accuracy of fire in the breech-loader would be more than compensated for, with muzzle-loaders, by the gain in the *number* of pieces.
>
> The relative merits of the two systems of breech-loading and muzzle-loading are clearly and forcibly stated by Sir William Armstrong, in his address before the Institution of Civil Engineers in January, 1882, as follows:
>
> "The question whether breech-loading or muzzle-loading guns are most advantageous is one which had been discussed in a very uncompromising spirit, as if one or other

of the two systems ought to be universally adopted, to the entire exclusion of the other. Impartial consideration, however, will show that there is room for both systems, and that each is best in its proper place. It has been distinctly proved that, so far as accuracy and velocity are concerned, there is nothing to choose between them. Neither is there any material difference in regard to rapidity of fire; nor would a superiority in this respect on either side be of much value, seeing that it is of far more importance to cultivate careful and deliberate fire than to facilitate a lavish expenditure of the very limited supply of costly ammunition that can be assigned to each gun in active service.

"With regard to convenience of loading and security of the gunners, the advantage is in most cases, though not in all, on the side of the breech-loader. Guns mounted on the broadsides of ships or in casemated batteries cannot be loaded at the muzzle by any known method without very seriously exposing the men to the fire of machine guns and small-arms. In fact, the great length of modern guns renders it impossible to get access to the muzzle for the purpose of loading without allowing more space for recoil than is practicable in a ship, or in the usually confined space of a casemate; so that in these cases breech-loading must be regarded as a necessity. But in earthwork batteries a muzzle-loading gun can, by proper arrangement, be loaded under the shelter of the parapet more securely and quite as conveniently as a breech-loader. In revolving turrets, also, a gun may be loaded at the muzzle by external means, involving no exposure of the men, and in gunboats carrying a heavy gun on the line of the keel, loading at the muzzle is also easily effected.

"The superior simplicity of a muzzle-loading gun entitles it to a preference wherever it can be used with equal advantage. All breech-loading mechanism is of a nature to require very accurate fittings, such as require care both in use and for preservation. Breech-loaders, therefore, are very unfit weapons for imperfectly instructed gunners, and they are quite out of place in open batteries where they would be exposed to the injurious influences of the weather and of drifting sand. It would be folly, therefore, in such cases to use them in preference to muzzle-loaders, which require little care for their preservation and take no harm from exposure."

To the above may be added the following extract from the conclusions of the Commission of Gavre in 1879 on the trials with M. L. rifled howitzers (Notes on the Construction of Ordnance, No. 8), namely:

> A rifled mortar for coast defense firing from behind an épaulement, whether muzzle or breech-loading, can only be loaded when the piece is nearly horizontal; in this position the difference in protection to the gunners by the épaulement with the breech-loader or the muzzle-loader is too trifling to be considered.
>
> A muzzle-loading rifled mortar for coast defense would have the following advantages over a breech-loader of the same kind: It is much more easily kept in repair, less costly, and can be more quickly manufactured; precautions, however, must be taken to sponge with care, and to have no stoppage of the projectile in the bore in the event of deformation of the sabot.
>
> With muzzle-loading mortars similar to those tried very satisfactory results can be obtained as to extent of range and accuracy; the accuracy in *range* exceeds that obtained with the best breech-loading pieces.

The 12-inch B. L. Rifle—cast iron.

This gun was completed and shipped to the proving ground in April of this year. After being subjected to the firing proof of 5 rounds with charges of 150 pounds of powder, as specified in the contract, some additional firings were made under the supervision of the Ordnance Board, for the purpose of determining the nature of the powder and the details of the band—for the projectile—best suited for testing the gun.

Experimental Firings.

The Department had procured last year a sample lot of brown prismatic powder from the United Rhenish and Westphalian Powder Company, Germany. This powder was guaranteed to fulfill the following conditions, imposed by the Department, when fired from a gun having the length of bore and size of chamber of the 12-inch cast-iron rifle, namely, with charge of 265 pounds; projectile of 800; density of loading, 0.84; and length of travel of shot in bore 22.6 calibers; to give a velocity of about 1,748 feet, with a pressure not exceeding 15.5 tons, or 34,720 pounds, per square inch of powder chamber.

The powder when tested in the 12-inch cast-iron B. L. rifle gave the following actual results:

Kind of powder.	Weight of charge.	Density of loading.	Weight of projectile.	Initial velocity.	Pressure per square inch of bore.
	Lbs.		*Lbs.*	*Feet.*	
German brown prismatic D. 1. 8628.........	265	0.8363	800	1,709	14.0 tons. 31,400 lbs.

These results were deemed satisfactory, and it was sought to reproduce them with a brown prismatic powder of home production, the Messrs. Du Pont having already furnished samples of brown powder for test. The results obtained with the Du Pont powder will be referred to more at length under the head of prismatic powder; suffice it to say here that they have proved so satisfactory that the Department has felt warranted, in advertising for bids for the supply of a considerable quantity of domestic brown powder, to impose the conditions that when fired in a gun of similar dimensions to this 12-inch cast-iron rifle, with a charge of 265 pounds, and a projectile of 800 pounds, the velocity shall not be less than 1,700 feet at 125 feet from the muzzle, and the pressure shall not exceed 32,500 pounds per square inch of powder chamber. The Ordnance Board has fired this gun 25 rounds, and has determined with sufficient definiteness the character of band to be employed with the projectile, to permit of the trials taking place as soon as the powder is procured.

A description of the manufacture of the gun and the records of firings are contained in Appendices 24 and 20 herewith.

The results thus far obtained, in the very limited number of rounds that have been fired, are to be regarded simply as a function of the length of bore and the quantity and character of powder employed, with a projectile of given weight, so that equally good results can with certainty be predicated of any gun, of equal caliber, fired under like conditions. It would, therefore, be premature as yet to pronounce the gun a success, as a piece of medium power, until it has first fulfilled the condition—*sine qua non*—of possessing the requisite degree of endurance under fire. But regarding the results simply from a ballistic point of view, the following tabular comparison is instructive:

Nature of cannon.	Caliber.	Weight.	Length of bore.	Powder.			Weight of projectile.	Ratio of weight—		Initial velocity.	Pressure per square inch of chamber.
				Kind.	Weight.	Density of loading.		Of charge to weight of projectile.	Of projectile to weight of piece.		
	Inches.	*Tons.*	*Cals.*		*Lbs.*		*Lbs.*			*Feet.*	*Tons.*
U. S. 12-inch B. L. rifle, cast-iron.	12	54	28	Brown powder.	265	.834	800	3.1	151	1709	14.0
Krupp's 30.5 cm. B. L. rifles, steel.	12	37	22	....do ...	264.6	.847	1,003	3.8	83	1556	15.6
	12	48	32	....do ...	357	.917	1,003	2.8	107	1857	17.3

From which we deduce—

Nature of cannon.	At muzzle.				At 3,500 yards.	
	Total energy, smashing effect.	Penetration in iron.	Energy per pound of powder.	Relative weight of gun to energy of projectile.	Total energy, smashing effect.	Penetration in iron.
	Foot tons.	*Inches.*	*Foot tons.*	*Tons.*	*Foot tons.*	*Inches,*
U. S. 12-inch B. L. rifle, cast-iron, 54 tons .	16,197	21.25	61.0	33.0	9,372	16.25
Krupp's 12-inch B. L. rifle, steel, 37 tons . .	16,834	21.75	63.5	22.0	10,899	17.5
Krupp's 12-inch B. L. rifle, steel, 48 tons . .	23,905	25.75	67.2	20.1	15,644	20.75

From the above figures it appears, comparing the 12-inch cast-iron rifle with Krupp's lighter gun, that, using practically the same weight of powder charge, the muzzle energy and penetration in iron are a little in favor of Krupp's gun; but the advantage of the heavier Krupp projectile is apparent in the still more favorable showing at 3,500 yards, where the difference in penetration is double what it was at the muzzle. The marked disparity between the guns lies (1) in the length of bore; the Krupp gun is much the shorter, and to offset which a heavier pressure is necessitated in the bore—though still a moderate pressure; and, (2,) in the weight of piece, the Krupp gun is the lighter by 17 tons.

If we assume the steel gun to cost \$1,000 per ton, and the cast-iron \$540 per ton, their total respective costs will be \$37,000 for the steel gun, and \$29,160* for the cast-iron gun, or a difference of \$7,840 in favor of the cast-iron. But the far greater weight and dimensions of the latter will require a carriage for its service, which, if not proportionately so heavy as that required for the Krupp gun, will yet be absolutely the heavier; it will also require a larger platform. These conditions will reduce materially the difference in cost, while the greater size and weight of carriage, added to the already objectionable weight of the cast-iron gun itself, will render pointing and elevating the gun slow if not tedious operations, and without the compensation of a proportional increase in the power.

---

* The actual cost of the 12-inch B. L. rifle, cast-iron, including the steel forging for breech mechanism and bushing, was \$29,153.

But then the question of *endurance* is still to be determined for the cast-iron gun, while it is an ascertained fact that the Krupp gun has been fired 120 rounds and is in good condition. If we disregard all consideration of weight of charge and length of bore, and make the comparison simply on the basis of weight of piece, the high-power Krupp 12-inch rifle of 48 tons will answer very well as representing the merits of steel against cast iron, though that gun is still 6 tons lighter than the 12-inch cast-iron rifle. The great superiority of this Krupp gun to the 12-inch cast-iron rifle, in smashing effect, which is assumed as the measure of effect against *hard armor*, and in piercing-power at all ranges, is at once apparent; nor is the pressure, 17.3 tons, deemed excessive for a steel gun. This Krupp 12-inch rifle has been fired over 100 rounds and remains in good condition. From this comparison it will be seen that the steel gun, of which this 12-inch Krupp is a type, would fulfill, far more satisfactorily the two prime conditions imposed on modern ordnance, viz, the attainment of the maximum power possible for the length of bore and weight of piece, and without overstraining the gun. In this connection the following extract from a communication addressed the by Chief of Ordnance to the Getty Board of 1882 is pertinent:

> If cast iron guns were once abandoned for the stronger built-up guns, why should we now return to them, when the great problem of the day is how to secure the gun of greatest power commensurate with our facilities for fabrication? If the built-up gun was better able to endure the more destructive powders of the past than the cast iron simply because it was a stronger gun, why should not its greater strength be utilized to-day in the attainment of a greater *power* than is admissible with cast iron? If *maximum power* is the object aimed at in the construction of modern artillery, there can be but one answer to this question. Indeed, stronger guns, not weaker ones, than even the best guns of the past are really what is needed to cope with the modern conditions of resistance to gun-power; more work is required from a gun now than formerly; and any increment of work that can with safety be exacted from it will be in full proportion to the increase of strength.

Another and a most instructive comparison may yet be made. A 10-inch B. L. rifle, steel, of 32 calibers length of bore would weigh about 27 tons. The results that should be realized with such 10-inch gun, reasoning from the results already obtained with Du Pont's brown powder in the 12-inch rifle, would be as follows:

Nature of gun.	Caliber.	Weight.	Length of bore.	Charge.		Weight of projectile.	Initial velocity.	Pressure per square inch of chamber.
				Weight.	Density of loading.			
	Inches.	*Tons.*	*Calibers.*	*Pounds.*		*Pounds.*	*Feet.*	*Tons.*
10-inch B. L. rifle, steel........	10	27	32	200	.900	600	1,857	17

From which we deduce, for comparison with the 12-inch rifle—

Nature of gun.	At muzzle.				At 3,500 yards.	
	Total energy, smashing effect.	Penetration in iron.	Energy per pound of powder.	Relative weight of gun to energy of projectile.	Total energy, smashing effect.	Penetration in iron.
	Foot-tons.	*Inches.*		*Pounds.*	*Foot-tons.*	*Inches.*
10-inch B. L. rifle, steel, 27 tons	14, 344	21. 8	71. 7	19. 0	8, 709	17. 1
U. S. 12-inch B. L. rifle, cast-iron, 54 tons.	16, 197	21. 25	61. 0	33. 0	9, 372	16. 25

From the above figures it will be seen that while the total energy, or smashing effect, is somewhat less for the 10-inch rifle up to 3,500 yards the depth of penetration is greater. But the weight of this gun is only one-half that of the 12-inch cast-iron gun, and therefore its *cost* would be about the same as for the latter. Should Congress make a sufficient appropriation to enable this Department to advertise for the forgings, say for 100 of these 10-inch steel rifles, it is quite certain that some of our steel manufacturers would provide the requisite press for the production of the forgings, with the oil tanks and annealing furnaces for their treatment, in about a year; and that they would begin to deliver the rough-finished forgings within six months afterwards, or say eighteen months after date of the contract. It is even safe to say that they would so design the new plant that it should possess sufficient capacity for the production of the forgings required for 12-inch steel guns; thus in the near future would our own steel makers be placed on a footing to supply the forgings for guns of a power far in excess of anything we can hope to obtain from the use of cast-iron alone. Liberal appropriations by Congress, to extend over a number of years, for the manufacture of 8, 10, and 12 inch steel rifles, and ultimately of 16-inch and higher calibers, would, it is believed, prove the truest policy for the development of our own resources, and the *surest* for placing our extended coast in a proper state of defense.

The remaining guns not yet completed are as follows:

The 12-*inch cast-iron B. L. Rifle, hooped and tubed.*

The body for this gun has been cast, and the steel parts, as hoops, tube and the forgings for breech mechanism, have been procured and are in such advanced stages of completion that the assembling of the parts will be commenced in a few weeks. The breech mechanism is also nearly completed. The hoops for this gun were obtained from the Midvale Steel Company, but, owing to their considerable dimensions and weight, the company feared that it would overtask their rolling mill to work these hoops as thoroughly as was done with the hoops for the 8-inch

rifle and 12-inch mortar; the effect of this is apparent in the somewhat lower qualities of these hoops, a mean of which for tangential specimens 6 inches long between shoulders, is as follows:

Elastic limit	24.5 tons. 54,880 pounds.
Tensile strength	47.0 tons. 105,280 pounds.
Elongation	13.6 per cent.

The 12-inch B. L. Rifle, cast iron, lined with wire-wrapped tube.

As stated in my last annual report, the first attempt to cast the body of this gun proved a failure; the flasks, proving too weak to sustain the weight of metal, gave way—precipitating the molten metal into the casting pit. The second casting for the gun was made December 23, 1884. After being removed from the pit the casting was placed in the lathe, and the cutting of annular grooves on the exterior begun, for the purpose of removing the surplus metal by means of wedges forced into the grooves.

In cutting a groove at 94 inches from the muzzle, and after a depth of about 7 inches had been reached, a crack was discovered at the bottom, and shortly afterwards the gun parted transversely along the crack—breaking short off in the lathe. Afterwards another crack was discovered in cutting a groove near the breech end; ultimately, as the cutting was continued, the casting cracked transversely at eight different points while the annular grooves were being cut, and before the resort to wedging off. (See Appendix 22, herewith.)

The failure of this casting is attributed to the irregular and abnormal strains—at least of abnormal intensity—induced by the method pursued in casting. A radical departure was made from the usually accepted Rodman method, and without the sanction of the Department; instead of cooling from the interior alone and keeping the exterior of the flask hot by a fire kindled at the bottom of the pit, a brick wall was set up in the pit around the flask and extending above the trunnions; then the space between it and the pit walls was filled in with damp molding sand. A fire was kindled on top of the molding sand, but was kept burning for only a comparatively short time. It is to these faulty arrangements, aggravated no doubt by a contraction in the mold near its upper portion—see Appendix 32—that, as it is believed, the loss of the casting was mainly due.

The company is now making arrangements for a third casting, to be made breech up.* The tube for this gun, the breech bushing and block, have been procured, and considerable work has already been done towards their completion. The tube will be wrapped with wire at the Watertown Arsenal.

*** Since writing the above, the third casting has been made. The official report states that it ruptured *longitudinally*, a fracture being found extending fromthe sinking head downward when the mold was stripped from the casting while yet in the pit.**

The 10-*inch B. L. Rifle, cast iron, wrapped with wire.*

The body for this gun has been sent to Watertown to receive its wrapping; the breech mechanism is nearly completed, and the wire will be applied as soon as some necessary data have been obtained from an experimental cylinder now being wrapped with wire.

The 10-*inch B. L. Rifle, steel, wrapped with wire.*

The tube for this gun, furnished by Sir Joseph Whitworth & Company, was rough-bored, turned, and annealed at the Washington Navy-Yard, and then shipped to the Watertown Arsenal. The longitudinal bars, for giving end strength to the gun, were cold-rolled at Jones & Laughlins, Pittsburgh, Pa., during which operation considerable delay was caused by several breakages of the rolls. (See Appendix 46.)

The forgings for the breech mechanism and the several exterior rings for the gun, except the cast-steel sleeve that is to sustain the trunnion-hoop, have already been furnished by the Midvale Steel Company; all of which, with some 33,000 pounds of finished and tinned wire, have been sent to the Watertown Arsenal, where the gun is to be constructed. The preparations at Watertown for winding the wire onto the guns are about complete, and preliminary trials are now being made to test the efficiency of the winding apparatus, and the effect produced by the wire on short cylinders representing sections of the guns under fabrication.

The drawing of the steel wire, of the character prescribed by the Department, has been a burdensome task to the wire makers, although experienced and skillful manufacturers, and it has proved a very severe ordeal to the metal itself, out of which the wire was made. See Appendix 47. At the date of this report the inspector gives the following as a tolerably fair estimate of the loss on 75,000 pounds:

	Pounds.
Shipped to Watertown Arsenal	33,000
On hand ready to tin	7,000
Probable amount that will be obtained from last lot of 18,000 pounds of rods	15,000
Total of good wire	55,000
Loss due to breaks, defective pieces, &c	16,000
Loss due to treating, pickling, &c	4,000
	75,000

Or a total loss of 26.6 per cent., which is certainly poor economy. Possibly it may be found practicable to reduce that amount by going over again the pieces rejected and saving portions of them. There is here, however, a wide field for improvement in means and methods; but improved methods will doubtless be forthcoming if the production of this class of wire is to take rank as a regular branch of the wire-making industry. The methods of production that must be employed for mere experimental purposes are necessarily more or less crude. Following is a summary of the results of tests made on specimens of this wire, and also on several varieties of imported wire used in gun construction abroad; all the specimens were 10 inches in length, and the tests were made on the machine at Watertown Arsenal:

	Cross-section of wire.	Tensile strength.	Elongation after rupture.	Reduction in area after rupture.
	Square inches.	*Pounds.*	*Per cent.*	*Per cent.*
American wire, Otis steel	.0216	176, 717	2.04	16.8
English ribband	.0147	270, 023	.47	15.43
French round wire for small calibers	.001257	309, 997	.47	22.01
French round wire for large calibers	.004926	828, 257	.77	16.57

The 8-inch B. L. Rifle, steel.

A second jacket has been furnished for this gun by Sir Joseph Whitworth & Company; all the material for the gun has been procured, sent to the West Point Foundry, and a large proportion of the machining has been done, and the manufacturers have begun to assemble the parts. A mishap, however, has already occurred in shrinking the jacket on the tube, which has occasioned considerable delay, but it will now soon be remedied.

Midvale Forgings for an 8-inch B. L. Rifle, steel.

The Department, last spring, contracted with the Midvale Steel Company for a tube, jacket, and forged trunnion-hoop for an 8-inch gun, intending, if these forgings should fulfill the contract requirements, to order afterwards the hoops for the gun. These are the largest gun-forgings yet attempted in this country, and the results are looked forward to with great interest, as they will, if successful, demonstrate the practicability of producing the steel for guns up to 8 inches caliber with the facilities now at the command of our own manufacturers. They will further show a step in advance towards the production of still larger forgings—an end earnestly to be desired, and to the speedy consummation of which a very material impetus would be afforded should the Department be enabled this year to place a considerable order for 8-inch gun-forgings. The physical qualities prescribed for these forgings were of very high character, such as is desirable for gun-steel—namely: tangential specimen 3 inches long for tube and jacket, and 6 inches long for the hoop, to show the following:

		Tube.	Jacket.	Trunnion hoop.
Elastic limit	pounds	48, 000	50, 000	45, 000
Tensile strength	do	90, 000	98, 000	95, 000
Elongation after rupture	per cent	21	19	15

The high reputation that the managers of the Midvale Steel Works have already acquired in the production of smaller gun forgings inspires the hope that they will also be successful with these of larger dimensions, although they are placed perhaps somewhat at a disadvantage, owing to the small size of their hammer. Both tube and jacket have been forged, and are now being rough-turned and bored prior to oil-tempering, and, so far as appearances go, are sound and good forgings.

The 10-*inch B. L. Rifle, steel hooped.*

The tube, jacket, and trunnion-hoop for this gun were ordered last spring from Sir Joseph Whitworth & Company, with the agreement that the forgings should be delivered in six months from the date of contract. The qualities specified for these forgings, and which Whitworth accepted without hesitation, were as follows: For tangential test specimens 3 inches long from tube and jacket and 6 inches long from trunnion hoop, viz:

	Elastic limit.	Tensile strength.	Elongation after rupture.
Tube	22 tons 49,000 pounds	42.4 tons 95,000 pounds	19 per cent.
Jacket	23 tons 51,500 pounds	43 tons 96,000 pounds	17 per cent.
Trunnion hoop	20 tons 45,000 pounds	42 tons 95,000 pounds	15 per cent.

Under date of July 28, 1885, the Department advertised for the hoops for this gun. The hoops were to be hammered, as their length was greater than could be furnished from any existing rolling-mill in the country, some of them being upwards of 2 feet in length. They were to be oil-tempered and annealed, as in the case of other hoops ordered and tested by the Department, and to show the following physical qualities as determined from the test of tangential specimens 6 inches long between shoulders:

QUALITIES.	
Elastic limit over	55,000 pounds.
Tensile strength over	100,000 pounds.
Elongation after rupture over	12 per cent.

The lowest offer for furnishing these hoops came from the Cambria Iron Company, Johnstown, Pa. These large and well-known steel producers had previous to this taken no active part in competing for the orders or contracts of the Department for supplies of gun steel; but it was well understood that the managers had the whole question of steel production, in the quantities and forms and of the qualities suitable to the necessities of the Department, under careful consideration, and had sent their officers abroad to collect information and to study foreign modes of practice. This office had previously received from the company the records of test of an oil-tempered and annealed locomotive tire, which were certainly promising, namely:

Elastic limit.	Tensile strength.	Ultimate elongation.	Reduction in area.
Pounds. 57, 180	*Pounds.* 110, 700	17. 5 per cent. in 2⅛ inches	47. 2 per cent.

Still it was a bold step to undertake, as their first attempt, the manufacture of these large hoops under such severe specifications; but it argues well for the enterprise and self-reliance of the Cambria Company.

Experimental Compound Cylinders.

In connection with the manufacture of experimental guns, the Department has made it a practice, in the case of each distinct type of gun, to assemble, with the shrinkages proposed for the gun, a short cylinder, representing a section of the gun through the powder chamber, and afterwards dismantle it. By this means it has been enabled to judge of the accuracy of the formulas employed for the calculation of the shrinkages and the radial changes corresponding thereto, when put to a practical application, and thus of the suitableness of the theoretical values to the purposes of actual construction; and incidentally it has derived additional information regarding the qualities of the metals employed.

From these experiments, so far as they have been carried, the satisfactory conclusions are reached—(1) that since the free tests of the metal, *i. e.*, as made with the testing machine, are fully confirmed by the results obtained from hooping cylinders, the data furnished from such free tests may be regarded as suitable for employment with the formulas relating to the hooping of guns; and (2) that the formulas themselves are to be regarded as safe guides in practice, at least as regards radial changes, when applied with the limitations under which they have been deduced.

The striking agreement between theory and practice, as regards the radial changes that occur in the wall of a compound cylinder under construction, where the values representing the qualities of the metals have been judiciously chosen, and the measurements of the radial changes skillfully made, will be apparent from an inspection of appendix 27, containing the report on the assembling and dismantling of an experimental cylinder for the 8-inch B. L. rifle, steel; whilst appendix 29—containing an analysis of similar experiments, made in connection with the construction of the 12-inch B. L. rifle, cast-iron, hooped, and tubed with steel—shows that even when allowing some latitude in the choice of the physical qualities, as, for instance, in the values of the co-efficients of elasticity, a satisfactorily close agreement is still obtained.

The accuracy of the theoretical values for the elastic resistance of compound cylinders, has not as yet been verified by experiment, and will accordingly be made the subject of future investigations, operating upon small cylinders by means of hydraulic pressure. From our present knowledge it would appear that the theoretical resistance, as computed by formulas now in use by the Department is too low, as measured by the registered powder pressures in the bores of guns, or, at least, that it may be considerably exceeded in practice without sensibly disturbing the elastic equilibrium of the gun. For instance, with the 12-inch mortar, hooped, the theoretical radial changes—corresponding to the actual shrinkages employed—were verified with a very fair degree of approximation in the actual construction of that piece.

But the corresponding theoretical elastic resistance of the system to an internal pressure was only about 11 tons; not taking into account, of course, the resistance of the casting due to its own initial tension of some 5 tons. Now this piece has, as a fact, been subjected to pressures in actual firing of 14, 15, and nearly 17 tons per square inch of bore, and yet without appreciable deterioration; indeed the measurements of the bore, after the firings, show a pretty regular contraction of about .001 inch on the diameter. (See Appendix 19.) Theoretically, a pressure of about 13.5 tons per square inch on the bore would have sufficed for the extension of the steel hoops to their elastic limit—the full elastic strength of the hoops not having been utilized in the construction, by reason of the over-compression of the casting that would have ensued, when the system is at rest.

The Department has now under preparation a series of experiments to test the frictional resistance exerted between cylinders assembled under shrinkage, the objects proposed being to ascertain the absolute value of such resistance in the cases under test, and also what relation the frictional resistance bears to the normal pressure, and to the extent of surface of contact where the pressure per superficial unit is constant. These experiments are regarded as of great importance in their bearing on the longitudinal strength afforded by the shrinking of one cylinder over another, and also on the coupling of tube with jacket in gun construction.

The complete records of the assembling and dismantling of the experimental cylinders representing sections of the 12-inch mortar, 8-inch rifle, and 12-inch cast-iron rifle, hooped and tubed, are contained in Appendices 26, 27, and 28.

The 8-inch Rifle, converted.

The contract for the 50 rifles, converted from 10-inch S. B. guns by lining with a steel tube, inserted from the muzzle, referred to in my last annual report, was awarded to the West Point Foundry Association as the lowest bidder, and the manufacture of the tubes, &c., to the Midvale Steel Company. The tubes were to be oil-tempered, and to show on 3-inch test specimens, taken tangentially from each end of tube, the following properties:

Elastic limit	38,000 pounds.
Tensile strength	80,000 pounds.
Elongation after rupture	Not less than 22 per cent.

The work on these guns is well advanced. (See Appendix 45.) The 50 casings have been bored out for the reception of the tubes, and upwards of 30 tubes, and a large proportion of the small forgings for breech cups and muzzle collars, have been accepted and sent to the West Point Foundry. With this lot of 50 guns the conversion of S. B. guns into rifles ceases, as the total number of converted rifles on hand will equal that recommended by the Senate select committee in February, 1883. Accordingly no appropriation for further conversions has been asked for.

Alterations of Sea-Coast Carriages.

This work has been delayed by the necessity of some further tests, but the original number of carriages undertaken for alteration for the 15-inch S. B. gun and the 11-inch M. L. rifle, converted, have been completed and are now being issued. The frequent applications made from the service for the 8-inch rifles, converted, with their mountings, has decided the Department to confine its alterations during this year to the 10-inch barbette and casemate carriages, adapting them to the service of the 8-inch rifles. This work will be done, as heretofore, at the Watertown Arsenal, and it is expected that 50 carriages will be completed this fiscal year.

Prismatic Powders.

The Messrs. Du Pont completed, last year, their new and large press for the manufacture of this kind of powder. It has a capacity for pressing 124 prisms at one time, and can turn out 12 pressings, or say 125 pounds of finished powder per hour. They have also devised a machine by means of which the ingredients of the powder are thoroughly blended together, the effect of which should be the production of a very uniformly burning powder.

A sample of the Du Pont brown prismatic powder was first tested in the 12.25-inch M. L. rifle of 18.5 calibers length of bore, last November, and its behavior as compared with that of the German prismatic powder may be judged from the following extract from the firing records of that gun.

Kind of powder.	Weight of charge.	Projectile weight.	Density of loading.	Velocity at 145 feet from muzzle.	Pressure per square inch of bore.
	Pounds.	*Pounds.*		*Feet.*	*Pounds.*
German brown prismatic......... D. 1.8628	175	693	0.99968	1,453	23,800
DuPont's brown prismatic .... D. 1.8600	175	692	0.99968	1,526	25,550

These results were promising, and another sample was ordered for trial in the 12-inch B. L. rifle, cast iron. The first sample tested in the latter gun proved entirely too slow-burning; the velocity and pressure were low, whilst a considerable quantity of partially consumed powder was ejected from the gun. Further samples were tested, and the present status of the Du Pont brown powder, as compared with the German, may be seen from the following extract from the firing records of the 12-inch cast-iron B. L. rifle (see Appendix 20):

Kind of powder.	Weight of charge.	Number of projectile.	Density of loading.	Velocity at 126½ feet from muzzle.	Pressure per square inch of chamber.
	Pounds.	*Pounds.*		*Feet.*	*Pounds.*
German brown powder D. 1.8628	265	800	0.8303	1,703	31,400
Du Pont's brown powder W. M D. 1.833	265	800	0.8363	1,700	26,300
Du Pont's brown powder N. M D. 1.833	265	800	0.8363	1,677	25,940

The last set of results represent a mean of 5 rounds, and are not so favorable as those in the preceding line. The latter are the best results thus far obtained with the 12-inch B. L. Rifle, all things considered, and will serve as the basis for future orders. The results, taken as a whole, are very satisfactory, and demonstrate the ability of our own manufacturers to equal, if not excel, the best results attained with powders in Europe. Great praise is justly due to Mr. Eugene Du Pont, for the ability and skill displayed in bringing, after such few trials, this new mode of manufacture to so successful an issue. It is understood that the English Government, after experimenting on the production of brown powder, finally purchased the secret of its manufacture from the German manufacturers at a price of £25,000.

Breech-loading Devices.

The 6.5-inch gun fitted with the Mann breech mechanism was tested and reported on last year. (See Appendix 23, Report of Chief of Ordnance, 1884.) The other gun, fitted with the Yates breech mechanism, has been in the hands of the Board for Testing Rifled Cannon, &c., since last February. Owing, however, to repeated changes made to facilitate the operation and fitting of the parts, up to date only sixteen rounds have been fired. A progress report on the test of this gun is contained in Appendix 48.

The Multicharge Gun.

This gun was disabled last year, at the 33d round, by the failure of the steel tube—a crack being developed that extended from the muzzle nearly to the front pocket. The gun was placed in a serviceable condition, however, by the application, under shrinkage, of steel hoops to the chase, and on December 10, 1884, the trials were resumed under the personal supervision of Mr. Haskell. The firings were continued until the 53d round, when the cast-iron casing of the gun gave way, cracking lengthwise in a line connecting the first and third loading holes. The effect of this rupture was to permanently disable the gun from further firing, and it was accordingly laid aside. The additional firing record of this gun is contained in Appendix 21.

Obturating Primers.

Primers of this class, both friction and electric, have been made and tested during the year, with fairly satisfactory results, at least with the friction primers; some slight modifications, however, seem yet to be desirable, and before manufacturing for issue to the service some additional tests have been directed.

High Explosives.

A considerable number of devices, involving the use of high explosives in projectiles, have been tested during the year—see appendices 9, 10, and 11. The experiments undertaken by the Ordnance Board have demonstrated the necessity of substituting for the ordinary explosive gelatine, heretofore used in their experiments, a camphorated variety, which shall prove less sensitive and more uniform in its action.

STEEL SIEGE B. L. RIFLE.

Under instructions from the Department, the Ordnance Board made a study, and submitted a plan of a steel siege gun. The caliber selected was 5 inches, the length of bore 30 calibers, and the weight 3,500 pounds, the breech fermature being the interrupted screw. The general design of the gun was similar to that of the 3.2-inch field gun—see appendix 22. On the recommendation of the Commanding Officer, Watertown Arsenal, Major Parker, to whom the plan was, by request of the Board referred for suggestions, some modification has been made in the original plan, and approved by the Department, namely: the jacket has been extended forward and under the trunnion-hoop; the length of bore has been reduced to 27 calibers, which is as long as the bore of any existing siege gun, and the walls of the chase made somewhat thicker to give greater stiffness; the maximum diameter is maintained over the entire breech portion. These modifications have increased the weight to about 3,700 pounds.

A contract has been entered into with the Midvale Steel Company for furnishing the forgings for this gun, which are to be oil-tempered and annealed steel, the prescribed qualities for the tube, jacket, and trunnion-hoop, as determined from test of tangential specimens 2 inches long, to be as follows:

	Tube.	Jacket.	Trunnion-hoop.
Elastic limit....pounds..	42,000	50,000	48,000
Tensile strength....pounds.	88,000	95,000	95,000
Elongation after rupture....per cent..	20	18	15

This gun will be manufactured at the Watertown Arsenal.

STEEL FIELD B. L. RIFLE.

The trial of the 3.2-inch B. L. steel gun, designed by the Ordnance Board for the field service, has been continued and completed during the past year by the Board for Testing Rifled Cannon, &c. The gun has been fired 1,556 rounds since the date of my last annual report—or 1,800 rounds in all. It is still in serviceable condition, and in the opinion of the Board has fulfilled the requirements of the law to the satisfaction of the Board, in that "it has been subjected to the proper test, including such rapid firing as a like gun would be likely to be subjected to in actual battle, for the determination of the endurance of the same." The Board accordingly recommends that this gun, or its modification, which is a slightly heavier model, is a suitable one "to be put to use in the Government service." The full details of the very complete and careful trial of the gun are contained in the report of the board. See Appendix 49. The piece has shown a satisfactory endurance, extent of range, and accuracy of fire, whilst the working of the breech mechanism has been almost unexceptionable. The following extracts, taken from the report of the Board, are interesting and suggestive of the character of the gun:

Pressures, velocities, and recoils.

Kind of powder.	Weight of charge.	Weight of projectile.	Velocity at 100 feet.	Pressure per square inch of powder chamber.	Recoil.	Remarks.
	Pounds.	*Pounds.*	*Feet.*	*Pounds.*	*Feet.*	
I K D. 1.225 Gr. 220	3.5	13	1,648	30,837	10.08	
L. X. A D. 1.706 Gr. 270	3.5	13	1,581	28,929	10.0	
L. X. B D 1.706 Gr. 270	3.75	13	1,740	34,600	....	Gun cold.
	3.75	13	1,749	35,083	....	Gun hot.

The maximum charge fired was 3.75 pounds, and the maximum velocity attained 1,749 feet; the maximum pressure to which the gun has been subjected is 37,250 pounds.

The mean range with an elevation of 20° was 6,479 yards, with a mean deflection to the right of 95.6 yards.

At a range of one mile the mean deviation was from 2.40 to 3.77 feet.

The rapidity of fire was, taking an average of more than 900 rounds, about 70 rounds per hour; the maximum and minimum rapidity, taking not less than 46 consecutive rounds, were as follows:

Maximum—46 rounds in 26 minutes, or a rate of 120 rounds per hour.

Minimum—50 rounds in 79 minutes, or a rate of 38 rounds per hour.

In the comparative trials made by the Commission of Belgrade, for the Servian Government, with a Krupp 3.3-inch gun, of the Dutch model, 1882, and a De Bange 3.15-inch gun, model of the French artillery, the rapidity of fire was as follows:

For the Krupp 3.3-inch gun, 30 rounds in 34 minutes, or a rate of about 53 rounds per hour.

For the De Bange 3.15-inch gun, 30 rounds in 22 minutes, or a rate of 82 rounds per hour.

(See "*Revue d'Artillerie*," January, 1885.)

It was also noted that after a rapid fire of 100 rounds, executed in 90 minutes, or at the rate of 66 rounds per hour, the temperature of the chase of the gun near muzzle was 370° F.

The maximum enlargement of the chamber after 1,800 rounds was .042 inch on the diameter, but no sensible enlargement occured after the 315th round.

The maximum enlargement of the rifled portion of the bore was from .03 inch on the diameter at 70 inches from the muzzle, to .008 inch at the muzzle; these enlargements were produced gradually and regularly with the firing of the gun.

The difference in diameter of bore as between the gun when cold and heated from firing was from .004-inch to .008-inch.

During the firing the piece required to be revented several times.

The steel field carriage developed a weak point in the side or cheek-plates, the angle iron riveted to the under side of the cheeks was broken, and the cheeks became distorted. This carriage was accordingly withdrawn. The cheek-plates are now being remodeled so as to offer a greater resistance.

The original design of this field gun has been subjected to some slight modifications, consisting mainly in the substitution of straight for curved lines over the breech portion and adding in other parts a little to the weight.

The Department has contracted with the Midvale Steel Company for the forgings for 25 of these field guns, 20 of which are to be manufactured at the West Point Foundry, and the remaining 5 at the Watertown Arsenal. The forgings for the tubes are to be oil-tempered and annealed, instead of being annealed simply, as was the case with the tube for the present gun, and the trunnion-hoops are to be forged instead of being cast. These forgings are required to fulfill the following conditions as to physical qualities, the test specimens being taken tangentially and of 2 inches length between shoulders:

	Tube.	Jacket.	Trunnion-hoop.
Elastic limit ....pounds..	42, 000	50, 000	48, 000
Tensile strength ....do.. ..	88, 000	95, 000	95, 000
Elongation after rupture ....per cent...	20	18	15

A number of the tubes, jackets, and other parts have already been delivered, and accepted as fully conforming to the contract requirements.

It is expected that the 25 guns will be completed early next spring.

MACHINE GUNS.

Under the appropriation for this purpose the Department has taken steps to procure a number of Hotchkiss, Gardner, and Gatling guns, for issue to the service.

I have the honor to submit the following papers, heretofore referred to:

Appendix 1.—Statement of principal articles procured by fabrication during the year ended June 30, 1885.

Appendix 2.—Statement of principal articles procured by purchase during the year ended June 30, 1885.

Appendix 3.—Statement of ordnance, ordnance stores, &c., issued to the military establishment, including the national homes for soldiers of the volunteer and regular Army, and exclusive of the militia, during the year ended June 30, 1885.

Appendix 4.—Apportionment for the fiscal year ending June 30, 1886, of the annual appropriation of $200,000 for arming and equipping the militia, under sections 1661 and 1667, Revised Statutes.

Appendix 5.—Statement of ordnance, ordnance stores, &c., distributed to the militia from July 1, 1884, to June 30, 1885, under section 1667, Revised Statutes.

Appendix 6.—Statement of arms, ammunition, &c., distributed to the Territories and States bordering thereon from July 1, 1884, to June 30, 1885, under the joint resolutions of July 3, 1876, March 3, 1877, and June 7, 1878, and the act of May 16, 1878.

Appendix 7.—Statement of ordnance, ordnance stores, &c., distributed to colleges from July 1, 1884, to June 30, 1885, under section 1225, Revised Statutes.

Appendix 8.—Report of action taken during the year ended June 30, 1885, under the provisions of the act approved March 3, 1881.

REPORTS OF THE ORDNANCE BOARD.

Appendix 9.—Test of 6-inch shells fired by the Dynamite Projectile Company. (1 plate.)

Appendix 10.—Test of 15-inch gun carriage altered at Watertown Arsenal.

Appendix 11.—Thayer's dirrigible balloon. (5 plates.)

Appendix 12.—Buckner's aerial drop for explosives. (1 plate.)

Appendix 13.—Firings with Hotchkiss mountain gun. (2 plates.)

Appendix 14.—Trial of banded 8-inch projectiles (experimental). (7 plates.)

Appendix 15.—Winslow's nitro-glycerine shells. (1 plate.)

Appendix 16.—Garrick's mortar and projectile for high explosives.

Appendix 17.—Trial of shells charged with explosive gelatine. (1 plate.)

Appendix 18.—Trial of Gardner machine guns. (4 plates.)

Appendix 19.—Preliminary trial of the 12-inch rifled mortar. (1 plate.)

Appendix 20.—Progress report on the trial of the 12-inch cast-iron breech-loading rifle.

Appendix 21.—Final firing and rupture of the 6-inch multicharge gun. (2 plates.)

Appendix 22.—Data for constructing 5-inch siege gun. (1 plate.)

ORDNANCE CONSTRUCTION.

Appendix 23.—Construction report of the cast-iron body for the 10-inch wire-wrapped breech-loading rifle.

Appendix 24.—Construction report of 12-inch cast-iron breech-loading rifle. (1 plate.)

Appendix 25.—Construction report of 12-inch cast-iron rifled mortar hooped with steel. (5 plates.)

Appendix 26.—Report on experimental cylinder from the 12-inch rifled mortar.

Appendix 27.—Report on an experimental compound gun cylinder, from 8-inch steel rifle. (4 plates.)

Appendix 28.—Report on experimental cylinder from the 12-inch cast-iron breech-loading rifle.

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Appendix 30.—Experiments with molten cast-iron in contact with oil-tempered steel. (1 plate.)

Appendix 31.—Subjecting oil-tempered steel to a high furnace heat. (2 plates.)

Appendix 32.—Annual report of Inspector of Ordnance at South Boston Iron Works. (1 plate.)

Appendix 33.—Computation of shrinkages, &c., for 8-inch steel rifle. (1 plate.)

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Appendix 35.—Proposed 12-inch and 16-inch breech-loading steel rifles. (1 plate.)

Appendix 36.—Inspection report of 8-inch, experimental, banded cored shot.

Appendix 37.—Inspection report of 8-inch Hotchkiss, banded, cored shot. (2 plates.)

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Appendix 43.—Wire drawing from steel billets at Trenton Iron Works.

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Appendix 45.—Converting cast-iron guns into 8-inch rifles with steel tubes. (1 plate.)

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Appendix 47.—Manufacture of steel gun wire at Trenton Iron Works.

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Appendix 54—Experimental carriage and ammunition cart for Gatling guns. (3 plates.)

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Appendix 56.—Metallic limbers for 3.2-inch field carriages. (6 plates.)

Appendix 57.—Metallic carriages for 3.2-inch steel gun. (1 plate.)

Appendix 58.—Metallic caisson and battery wagon for field service, and wagon for ammunition column. (5 plates.)

Appendix 59.—Artillery machines. (1 plate.)

Appendix 60.—Metallic carriages for Gatling guns. (6 plates.)

Appendix 61.—Showing the Stations and duties of the officers of the Ordnance Department.

I have the honor to be, very respectfully, your obedient servant,

S. V. BENÉT,
Brigadier-General, Chief of Ordnance.

To the Hon. SECRETARY OF WAR.

APPENDIX 1.

Statement of principal articles procured by fabrication during the fiscal year ended June 30, 1885.

CLASS II.

35	gun carriages for Life-Saving Service.
20	metallic carriages and limbers for Gatling guns.
1	field caisson and limber.
1	battery wagon and limber.
4	metallic limbers for 3.2-inch rifle.
7	carriages and chassis for 15-inch gun.
1	"Brewers" carriage and chassis for 15-inch gun.
1	"Timbys" carriage and chassis for 15-inch gun.
3	carriages and chassis for 11-inch rifle.
6	barbette carriages and chassis for 8-inch rifle.
2	casemate carriages and chassis for 8-inch rifle.

CLASS III.

3	breech-sights for Hotchkiss mountain guns.
4	breech-sights for Hotchkiss revolving cannon.
7	breech-sights for 3.2-inch rifles.
2	breech-sights for 12-pounder mountain howitzer.
50	breech-sights for 8-inch rifles.
10	iron water buckets.
15	maneuvering bars.
6	elevating bars for 15-inch gun.
6	elevating arcs and indices for 8-inch rifles.
2	fuze blocks.
4	fuze plug wrenches.
16	gunners' gimlets.
12	gunners' pincers.
4	gun covers for Gatling guns.
1	gun cover for 12-pounder mountain howitzer.
35	gunners' haversacks for Revenue Marine Service.
3	handspikes.
232	sets artillery harness for 2-wheel horses.
150	sets artillery harness for 2-lead horses.
34	harness sacks.
50	lanyards.
93	muzzle or front sights.
70	powder measures.
57	priming wires.
1	pouch for sights.
35	quoins for Life-Saving Service.

20	oilers for Gatling gun carriages.
3	plummets.
100	securing stakes.
2	pendulum hausses for 12-pounder guns.
2	shot carriers.
48	sponge covers for 3-inch rifles.
4	sponge covers for 12-pounder guns.
35	sponge covers for 2½-inch life-saving guns.
1	sponge and rammer for Hotchkiss mountain gun.
16	sponges and rammers for 12-pounder mountain howi
12	sponges and rammers for 12-pounder guns.
148	sponges and rammers for 3-inch guns.
35	sponges and rammers for 2½-inch life-saving guns.
6	thumbstalls.
126	tompions for 3-inch rifles.
2	tompions for 3.2-inch rifles.
124	tompions for 12-pounder guns.
7	tompions for 10-inch rifles.
13	pendulum hausse pouches.
600	vent gimlets.
114	vent covers.
600	vent punches.
29	vent pieces.
32	wipers for mortars.
35	wipers for 2½-inch life-saving guns.
2	water tubs.
4	worms and staves for 3-inch rifles.
2	worms and staves for 12-pounder guns.

CLASS IV.

522	3-inch Eureka shot.
979	4.2-inch Eureka shot.
30	8-inch shot.
522	3-inch Eureka shells.
2, 465	3.2-inch shells.
1, 500	3.2-inch case shot.

CLASS V.

13	3.2-inch wire canister.
7	8-inch service canister.
9	8-inch choke canister.

CLASS VI.

37, 557	Springfield rifles, caliber .45.
100	officers' rifles, caliber .45.
2, 500	Springfield cadet rifles, caliber .45.
500	Springfield shotguns.
500	officers' swords.
5, 000	hunting knives.

CLASS VII.

ARTILLERY ACCOUTERMENTS.

11	knapsacks for light batteries.

CAVALRY ACCOUTERMENTS.

4, 500	carbine slings.
2, 600	saber belts.
84	saber-belt plates.

INFANTRY EQUIPMENTS.

5, 900	bayonet scabbard.
10, 237	bayonet scabbard bodies.
10, 135	blanket bags.
10, 135	blanket-bag shoulder straps.
10, 925	pairs coat straps.
9, 049	cartridge boxes, pattern 1874, McKeever.
200	cartridge boxes, caliber .45, with wood blocks.
11, 600	canteens.
9, 650	canteen straps.
1, 250	cartridge-belt plates.
222	frogs, sliding.
15, 269	gunslings.
8, 925	haversacks.
6, 800	haversack-straps.
5, 000	hunting knife scabbards.
470	meat cans.
750	magazine belts for Lee rifle.
100	officers' sword belts.
12	shoulder belts and plates.
30	sheaths for intrenching tools.
4, 945	tin cups.
3, 301	waist belts.
2, 421	waist-belt plates.
6, 455	waist belts and plates.
750	waist belts, black leather.

APPENDAGES.

33, 000	headless shell extractors.
11, 720	front sight covers for rifles and carbines.
28, 766	screw-drivers.
18, 650	wooden wiping-rods.

HORSE EQUIPMENTS.

4, 701	bridles, curb, cavalry.
1, 021	bridles, watering.
5, 061	bits, curb, cavalry.
2, 783	cinchas, or hair girths.
10, 180	curry combs.
1,001	halters and straps.
7,271	horse brushes.
500	horse covers.
1,000	lariats.
2,000	saddles, cavalry, leather covered.
65	saddle cloths, hair.
5,300	spur straps.
34	brush and shoe pouches.

CLASS VIII.

33,496	blank cartridges, 3-inch gun.
4,463	blank cartridges, 6-pounder gun.
6,800	blank cartridges, ½ pound.
1,730	blank cartridges, 1 pound.
2,000	blank cartridges, 2 pound.
9,125	blank cartridges, 12-pounder mountain howitzer.
28,005	blank cartridges, 12-pounder gun, light.
300	blank cartridges, 12-pounder gun, heavy.
60	blank cartridges, 3.2-inch gun.
3,301,187	rifle ball cartridges, caliber .45, reloading.
848,520	rifle and carbine blank cartridges, caliber .45, reloading.
1,763	rifle ball cartridges, caliber .45, experimental.
1,619,626	carbine ball cartridges, caliber .45.
863,608	revolver ball cartridges, caliber .45, reloading.
141,310	revolver blank cartridges, caliber .45, reloading.
6,490,960	rifle bullets, caliber .45, 500 grains.
1,980,413	carbine bullets caliber .45, 405 grains.
1,868,000	round balls, caliber .45.
300,000	revolver bullets, caliber .45.
100	paper fuzes, 5 seconds to the inch.
100	paper fuzes, 8 seconds to the inch.
100	paper fuzes, 12 seconds to the inch.
100	paper fuzes, 15 seconds to the inch.
200	paper fuzes, 20 seconds to the inch.
100	paper fuzes, 25 seconds to the inch.
43	metallic time fuzes.
209,800	friction primers.
5,150	electric primers for cannon.
20	Krupp's cannon primers.
75	friction obturating primers.

CLASS IX.

300	blocks.
22	half-blocks.
28	quarter-blocks.
3	snatch blocks.
2	capstans.
8	capstan bars.
2	gun chocks.
54	roller chocks.
1	gun collar.
1	cradle for heavy guns.
5	gin falls.
10	handspikes, gin.
14	rollers, long.
12	rollers, short.
30	shifting planks.
38	skids.
7	sling chains.
1	sling-cart, small.
1	trunnion loop.
2	platforms for mortars.
9	platforms for siege carriages.
60	Elliott's intrenching tools.

30	trestles for siege mortars.
1	gun-lift for 15-inch gun.
1	implement and tool cart.
1	Sanger's gun shield.
10	marking outfits.
30,000	marksmen's buttons.
7,650	marksmen's pins.
4,000	sharpshooters badges.
60	leather bags for intrenching implements.
1	trace rope.
1	tripod, sighting.
63	disks.
19,054,000	pasters for targets.
417	signal flags.
120	shot marks.
263	streamers for rifle range.
166	targets, Laidley, revolving.
2	targets, Brinten.
30	targets, Cushing.
1	target, Lancaster.
1	target, Texas.
61,600	paper targets.
1,672	target frames.
1	plane table.

RELOADING TOOLS.

12	adjustable chargers, Michaelis.
100	chargers.
415	reloading dies.
499	resizing dies.
280	priming tools.
1	primer punch.
405	combination anvils.
135	drifts.
265	funnels.
478	reloading punches.
294	resizing punches.
201	shell scrapers.
200	wiping rods.

CLASS X.

1	metal ammunition chest.
1	shaft for Laidley cavalry forge.
6	poles for artillery carriages.
4	middle rails for field caissons.
4	brass boxes for 15-inch carriages.
16	bolts and nuts for 15-inch carriages.
3	cylinder straps for 15-inch carriages.
8	forks for field limbers.
6	foot boards for field limbers.
8	hounds for foot limbers.
80	trunnion rings, eccentric for 8-inch B.L. rifle
8	shoes for No. 1 wheels.
74	collars.
62	leg guards.

6	breast straps.
24	collar pads.
1	seat (front sight) for 3.2-inch gun.
1	thumbscrew for rear-sight of Hotchkiss gun.
12	splinter bar traces.
12	rammer heads for 30-pounder Parrott.
115	woolen sponges for 3-inch rifled guns.
20	woolen sponges for 12-pounder mountain howitzer.
12	woolen sponges for 8-inch rifle.
6	woolen sponges for 15-inch guns.
600	copper bands for 3.2-inch shells.
100	bushings for 4.5-inch Butler shells.

SPARE PARTS OF SPRINGFIELD RIFLE AND CARBINE, VIZ:

2124	stocks (wood part) Springfield rifle.
171	tips.
169	tip screws.
1,950	ramrod stops.
464	band springs.
490	side-screw washers.
308	butt plates.
850	butt-plate screws.
153	butt-plate covers.
204	cover-springs.
35	cover-spring screws.
128	cover-friction springs.
200	cover-stud pins.
420	guard plates.
238	guard bows.
643	guard-bow swivels.
780	guard-bow swivel screws.
304	guard-bow nuts.
11,278	triggers.
994	trigger screws.
1,055	guard screws.
4,748	rear-sight bases.
2,962	rear-sight base springs.
1,288	rear-sight base screws.
2,005	rear-sight leaves.
308	rear-sight slides, complete.
1,068	rear-sight slide plates.
1,468	rear-sight slide blocks.
4,619	rear-sight slide springs.
2,034	rear-sight slide screws.
182	rear-sight centering pins.
524	rear-sight joint pins.
3,747	rear-sight buckhorn plates.
2,679	rear-sights, complete.
47	barrels, complete.
5,795	extractors.
2,582	hinge pins.
4,175	ejector springs.
894	ejector-spring spindles.
972	ejector studs.
61	cam latches.

494	breech-block caps.
370	thumb pieces.
1	breech block.
121	breech-block cap screws.
10,519	firing pins.
2,713	firing-pin screws.
1,953	cam-latch springs.
53	breech screws.
1,320	front sights.
1,232	front-sight rivets.
1,643	tang screws.
183	bands, upper.
200	band swivels.
14	band-swivel pins.
645	bands, lower.
187	lock plates.
510	main springs.
369	main-spring swivels.
582	main-spring swivel rivets.
449	hammers.
3,935	tumblers.
1,291	tumbler screws.
594	bridles.
2,291	bridle screws.
2,587	sears.
2,473	sear screws.
359	sear springs.
1,486	sear-spring screws.
101	locks, complete.
1,243	side screws.
1,570	ramrods.
366	bayonet clasps.
348	bayonet-clasp screws.
1,688	bayonets, complete.
100	swivel bases.
100	swivel bars.
2	swivels, complete.
181	stocks, complete.
87	band gun-sling swivels.
52	band stacking swivels.
2	bands for officers' swords.
1	blade for officer's sword.
1	hilt for officer's sword.
2	scabbard tips for officers' swords.
4	scabbard-tip screws for officers' swords.
50	guards for cavalry officers' sabers.
100	broad sword blades, wood.
3,039	pistol grips.
263	pistol-grip screws.
200	rod bayonet springs.
600	rear-sight gibs.
3	barrels and receivers for Springfield shotgun.
10	front sights for Springfield shotgun.
1	bolt for Chaffee-Reece rifle.
1	cartridge-lifting spring for Chaffee-Reece rifle.
10	ejector springs for Chaffee-Reece rifle.

10	extractors for Chaffee-Reece rifle.
10	firing pins for Chaffee-Reece rifle.
20	main springs for Chaffee-Reece rifle.
19	extractors for Springfield shotgun.
2	stocks (wood part) for Springfield shotgun.
1, 012	firing-pin springs.
2, 000	buckles, bar, brass, ¾ inch.
10, 000	buckles, wire, brass, ¾ inch.
6, 457	canteen covers.
140	hooks, brass, for canteen straps.
904	cartridge blocks, caliber .45 "R. I. M."
80	thongs, lacing for cartridge belts.
500	bridle reins.
894	cincha straps.
1, 000	curb straps.
5, 000	fasteners for side lines.
3, 036	foot staples, brass.
271	girth straps.
4, 100	halter straps.
500	headstalls for bridles.
10, 000	hooks, double S.
50	hook straps.
1, 485	halters.
498	girth safes.
100	loops for saber-belt plates.
2, 048	ovals, guard-plate.
300	rings, iron, 2½ inch.
5, 000	staples for rings.
2, 000	stirrup straps.
70	slides, brass, with hooks.
50	saber hooks and bands.
16	staples for valise straps.
1, 352	cartridge bags, ½ pound.
20	cartridge bags, 1 pound.
520	cartridge bags, 2 pounds.
10, 854	cartridge bags, 3-inch gun.
6,500	cartridge bags, 6-pounder gun.
300	cartridge bags, 10-inch Rodman gun.
31,850	cartridge bags, 12-pounder gun.
2,450	cartridge bags, 3.2-inch breech-loading chambered rifle.
15,000	cartridge bags, 12-pounder mountain howitzer.
200	cartridge bags, 6.5-inch Mann rifle.
19	cartridge bags, 12-inch breech-loading rifle.
2,879,000	carbine cartridge wads.
11,791,000	cartridge primers.
6,160	cartridge shells, rifle.
20,000	cartridge shells, revolver.
33,490	cartridge shells, shotgun.
1,745	parts of Laidley revolving targets.
43	parts of Cushing target.
12	washers for reloading punch.
12	caps, crimping die.
100	tools, primer box.
1	plug, ganging, resizing die.
2	screws, priming tool spindle.
1	mallet for reloading tools.
2	poles for sling cart.

MISCELLANEOUS.

2,014	arm chests.
4,602	boxes, packing.
10	boxes, packing, tin.
321	cans, tin.
1	case, office.
201	boxes reloading tool.
100	boxes, paper.
200	bags for powder.
1	set harness.
15	aprons, smiths'.
1	block, priming, lead.
296	brushes.
87	bits, assorted.
50	quarts blacking for leather.
1	caliper.
1	cart.
413	chisels, various.
20	clamps, saddlers'.
500	chamois-skin cases for swords.
936	disks, pressure, copper.
377	dies, various.
866	drills.
36	cylinders, crusher-gauge.
600	cylinders, copper.
115	boxes cleaning material.
5	funnels.
1,089	files, assorted.
363	files, rotary.
350	pounds fulminate of mercury.
134	gauges, assorted.
2	gas-checks (De Bange).
420	pounds grease, wheel.
4	gauges, ring, for setting star gauge.
2	gauges, ring, for projectiles.
2	gauges, fuse thread.
1	gauge, expansion caliber.
2	gauges, pressure.
10	hammers.
14	horses, saddlers'.
158	boxes, ingredients for leather blacking.
80	gallons lacker.
28	mallets.
1	machine, milling.
1	machine, bullet-lubricating.
1	machine, bullet-pressing.
1	machine, cartridge-heading.
1	marker for cartridge bags.
1	set model rifle-ball cartridge, caliber .50.
1	model rifle bullet, caliber .50.
3	molds, fuse plug, 3.2″ projectile.
6	molds, lead bar.
10	measures, tin.
1,554	mills, armorer's.
104	mandrels.

11	measuring points, star gauge.
2	mauls.
7, 346	pounds oil, harness.
4	punches, assorted.
171	pounds paint, black.
1, 750	pounds paint, olive.
2, 300	pounds paint, assorted.
2	pounds putty.
10	plates, wrought-iron.
16	pans, dust.
5⅝	pounds polish for leather.
50	pounds polishing materials.
482	racks, arm, portable.
389	reamers.
8	rods, measuring, adjustable.
1	scale, pressure.
2	scrapers, iron.
14	pair slippers, magazine.
10	sets stamps, figures.
3	stamps, seal.
1	star gauge.
826	parts of stoves.
10	pounds scouring materials.
1	set stencil outfit.
2	star-gauge guides.
2	scoops.
3	stamps, shell and flame.
1	star-gauge support.
207	taps, various.
885	tools for current service.
1	set fuse tools.
1	templet, fuse.
2	templets, screw-thread 8-inch rifle.
2	sets tools, crusher-gauge.
1	set tools, obdurating primer.
2	one-horse wagons.
70	pounds wax, black.
8	wheelbarrows.
1	wrench and tap for vent piece.
1	wire inspecting instrument.
12	iron posts for military reservation.
1	pair pole straps, draught harness.
1	grindstone frame.
15	tree guards.
7	button sticks.
2	straps, steel.

APPENDIX 2.

***Statement of principal articles procured by purchase during the fiscal year ended June* 30, 1885.**

CLASS I.

1	8-inch, Yates, breech-loading rifle, converted.
1	6½-inch, Mann, breech-loading rifle, converted.
1	12-inch rifled mortar, hooped with steel.
32	Gatling guns (10 barrel), caliber .45.
1	Hotchkiss rapid firing cannon, 57^{mm}.

CLASS II.

4	Ammunition chests for Hotchkiss rapid-firing cannon, 57^{mm}.

CLASS III.

8	chocks, 15-inch gun.
14	buckets.
20	feed-cases, Gatling gun, caliber .45.
128	feed-magazines, Gatling gun, caliber .45.
4	gun scrapers.
2	mortar wipers.
100	paulins 12 by 15 feet.
8	pinch bars.
19	sight seats for guns.

CLASS IV.

300	15-inch solid shot.
309	12 inch cored shot.
308	12-inch mortar shell.
1,010	8-inch Butler shot.
25	8-inch Butler shell.
6	8-inch steel shot.
223	8-inch Hotchkiss shot.
4	8-inch nitro-glycerine shell.
6	6-inch dynamite shell.
500	steel shell for Hotchkiss rapid-firing cannon, 57^{mm}.
500	empty metallic cases for Hotchkiss, 57^{mm} gun.
8	glass bottles for shell.

CLASS VI.

550	Hotchkiss magazine rifles, caliber .45.
750	Lee magazine rifles, caliber .45.
2,000	Colt's revolvers, caliber .45.

Class VII.

2,119	saddle blankets, cavalry.
16	curry combs.
4	horse brushes.
3, 550	sets knives, forks, and spoons.

Class VIII.

1, 200	pounds blasting powder.
10, 179¾	pounds brown prismatic powder.
17, 100	pounds hexagonal powder.
40, 000	pounds mortar powder.
121, 500	pounds musket powder.
700	pounds square powder.
500, 000	rifle-ball cartridges, caliber .50.
115, 000	rifle-ball cartridges, caliber .45.
20, 000	primed shells, caliber .50.
350	Hotchkiss base fuzes.
100, 000	lubricated bullets.
400	paper shells.
112, 000	primers for cartridges.
27, 150	pounds drop shot.
1, 152, 000	wads.
22	feet safety fuze.

Class IX.

8	double blocks.
6	single blocks.
5	pulley blocks.
2	quadruple blocks.
3	tackle blocks.
5	triple blocks.
1	gin fall.
3	gin slings.
6	hydraulic jacks.
5	lifting jacks.
24	steel pins for 15-inch carriage.
3	sling chains.
44	steel wheels for 15-inch carriage.
52	steel rollers for 15-inch carriages.
40	white-oak rollers.
8	iron rollers.
4	gun slings (rope).

Class X.

4, 464	bar buckles.
189¼	pounds escutcheon pins.
2, 208	halter bolts.
4, 452	halter squares.
11, 349	roller buckles.
6, 444	rings.
8	saddle-trees.
307	8-inch Butler sabots.
200	12-inch mortar sabots.
8, 670	spring snaps.

8	pairs stirrups.
9,709	gun stocks.
500	tin straps for sabots.
80	wheels for artillery carriages.
4,278	parts of Colt's revolver.
80	parts of Gatling gun.
125	parts of Hotchkiss gun.
89	parts of Hotchkiss magazine rifle.
105	parts of Lee magazine rifle.
900	parts of Scofield, Smith & Wesson revolver.
100	parts of rifles.
30	parts of infantry equipments.
47	parts of gun carriages.
24	pintle-bolsters for sea-coast carriages.
156	rubber buffers for 15-inch carriages.
20	gun checks, Mann 6½-inch breech-loading rifle.
100	copper bands, Mann 6½-inch projectiles.
1	set loading tools, Hotchkiss rapid-firing cannon, 57^{mm}.
10	bands, 12-inch Hotchkiss shot.

PART SECOND: CLOTH, ROPE, THREAD, &C.

132	yards burlaps.
32	yards cloth, oiled and enameled.
6	yards cloth, woolen.
12	yards cloth, rubber.
62,218¼	yards cotton cloth.
657	yards cotton, felt, and petersham.
7,472	pounds cotton waste.
1,709⅜	pounds cord and twine.
1,253	yards cord and twine.
12¾	yards canvas.
31	yards carpeting.
51	yards canton flannel.
328¾	yards flannel.
2,246	pounds hair.
105	pounds marline.
100	feet marline.
52	pounds moss.
20	yards matting.
145	pounds oakum.
10,365¾	pounds rope.
39	pounds sewing silk.
36	spools sewing silk.
100	yards tape, braid, &c.
1,877¾	pounds thread.
94	spools thread.
5	yards ticking.
112	towels.
35	yards toweling.
36,288	yards webbing.
34⅔	yards window shades.
44	window shades.
45	pounds yarn.

FORAGE.

17,551	pounds barley.
19,935	pounds bran.
391	bushels corn.
28½	barrels flour.
22	bushels grass-seed.
9,405	pounds ground feed.
200,641	pounds hay.
22,634	pounds meal.
8,349¾	bushels oats.
10	bushels rye.
20	bushels salt.
1,510½	pounds salt.
88,545	pounds straw.

IRONMONGERY.

60¾	pounds babbitt metal.
36	bath-tubs and fixtures.
506,340	pounds I and channel beams.
7	bells.
22	blind-fasteners.
3	boilers.
7,761	bolts.
127	pounds bolts.
5	pounds brads.
136	papers brads.
61¼	pounds brass rods.
62	feet brass rods.
2,801½	pounds sheet brass.
100	buckles, assorted.
103½	pounds burrs.
536	buttons.
3	sets castors.
2,507	pounds bronze and brass castings.
99,166	pounds iron castings.
70	iron castings.
384	pounds steel castings.
2,260½	pounds chain.
6,182	feet chain.
433	cocks, assorted.
14,369⅛	pounds bar copper.
263,392½	pounds cartridge copper.
15,833¼	pounds sheet copper.
42	couplings.
1	set couplings.
97	door-catches and fixtures.
19	escutcheons.
30,144	eyelets.
397	gas burners.
614	gas fixtures, assorted.
18	papers glazier's points.
952	pennyweights gold.
1,480	pounds grate-bars.
1,186	pairs hinges.
1,248	hooks, assorted.

9,908	horseshoes.
525	pounds horseshoe nails.
28	hose fittings.
4,471½	pounds hoop iron.
$85\frac{5229}{2240}$	tons pig iron.
5,471	pounds sheet iron.
316,905	pounds wrought iron.
108	keys.
221	knobs, assorted.
4,589	pounds lead
1,198	locks, assorted.
57,548¾	pounds nails.
120	nails, assorted.
269	nuts, assorted.
7,643	pounds nuts, assorted.
16½	pounds brass pipe.
42½	pounds copper pipe.
504½	pounds iron pipe.
25,919¼	feet iron pipe.
6,382¼	pounds lead pipe.
1,550½	feet lead pipe.
13	pounds pipe fittings.
4,392	pipe fittings, assorted.
3	pumps.
221	pulleys.
213	radiators.
17	reducers.
4,586¾	pounds rivets, assorted.
6,000	rivets, assorted.
1,263	pounds rivets and burrs.
110	rollers.
659½	feet metallic rope.
640	pounds sash weights.
4,486½	gross screws, assorted.
1,664	screws, assorted.
110	gross screw-eyes, &c.
230½	pounds German silver.
61,95[illegible]	pennyweights silver.
10	sinks.
531½	pounds solder.
10,660	pounds spikes.
41½	pounds springs.
18	springs.
736,525⅞	pounds bar and plate steel.
3,361	pounds steel forgings.
15,216	pounds sheet steel.
6	pounds staples.
34	staples.
2,117,041	tacks.
237¼	pounds tacks, assorted.
62,159¾	pounds block tin.
1,011½	pounds tin-foil.
109¼	boxes sheet tin.
2,444	square feet tin.
210¼	pounds tubing.
12	feet tubing.

199¼	pounds washers.
696	washers.
171	water closets and fixtures.
6,036⅝	pounds brass wire.
16,807	pounds copper wire.
500	feet copper wire.
757½	feet wire cord.
27½	pounds German-silver wire.
17,456¾	pounds iron wire.
226¼	feet platinum wire.
1,214	feet wire grating and netting.
134½	square yards wire cloth.
5,150⅜	pounds steel wire.
1,764	wire ferrules, assorted.
263	window fixtures.
2,519	pounds zinc.
300	tin-can screws.
110	lightning fixtures.

LEATHER, HIDES, &C.

1,900	feet belt lacing.
1,642¼	pounds bristles.
334⅜	pounds black wax.
5	pounds apron leather.
9,016¼	feet leather belting.
294	pounds buff leather.
72,725¾	square feet collar leather.
1,076	sides collar leather.
106¼	pounds bellows leather
2,575	sides bridle leather
32,346¼	pounds harness leather
3,210½	square feet bellows leather.
17	sides lace leather
274⅞	pounds lace leather.
356⅞	pounds sole leather.
69	pounds walrus leather.
55	feet rubber belting.
8	sheep-skins.
6	sides horse-hide.

LUMBER.

880	feet battens.
852,404	feet boards.
96	feet joists.
148,400	laths.
320,034	feet plank.
208	feet posts and rails.
350	posts and rails.
123,726	feet scantling.
150,000	shingles.
79,993	feet timber.

BUILDING MATERIAL

30	pounds asbestus.
65½	square feet asbestus.
166	loads blocks (stone).

99	yards bordering paper.
44	brackets.
695, 100	bricks.
1, 464	barrels cement.
88	feet cement pipe.
48½	barrels clay
4, 605½	bushels clay.
49	doors, wood.
180	drain pipes.
4, 423	feet drain pipe.
3, 118¾	square feet flagging stone.
2, 106	feet window glass.
4, 003	lights window glass.
64	loads gravel.
75	bushels plastering hair.
2	flights iron stairs.
1, 953¾	barrels lime.
1, 538½	bushels lime.
214	loads loam.
8	mantels.
2, 049	feet molding.
33⅓	pounds plaster of Paris.
10	barrels plaster of Paris.
540½	cubic yards sand.
2, 734	bushels sand.
7, 782	square feet slate.
576	slate.
12, 186	cubic yards stone.
1, 000	feet tarred paper.
728	pounds tarred paper.
1, 524	feet terra-cotta pipe.
44	terra-cotta traps, &c.
1, 409½	feet tiles.
55	rolls wall-paper.
89	feet water spouts.
368	yards weather strips.
50	pairs window blinds.
103	pairs window sash.
42	window sash.
53	feet brown stone.
36	barrels stucco.

HEATING, LIGHTING, &C.

30	bath bricks.
208	quarts blacking for leather.
1, 212	brooms.
204	brushes, dusting, &c.
55	pounds candles.
127	pounds card-clothing.
277½	square feet card-clothing.
24, 985	bushels charcoal.
39	barrels charcoal.
11	chandeliers.
514	chamois skins.
2, 886	tons anthracite coal.

2, 654	tons bituminous coal.
124, 900	pounds coke.
498	bushels coke.
3, 126	pounds corundum.
442	corundum and emery wheels.
52	reams crocus and emery cloth.
920½	pounds emery.
4 6/20	reams emery paper.
26	sets fire-brick.
12, 000	fire-bricks.
316¼	cords fire-wood.
30	grates.
11, 775	pounds kaolin.
27	lanterns.
2	lamps.
307	lamp-fixtures.
96	lamp-wicks.
15	pounds lampwick.
33¾	gross matches.
4, 003	pounds mineral wool.
16	mops and handles.
44	pounds paraffine.
16	pitchers, jugs, &c.
113½	pounds pumice stone.
7	registers.
476½	pounds rosin.
688½	pounds rotten-stone.
9¾	pounds rubber cement.
83½	reams sand-paper.
51	cakes sapolio.
6, 037	pounds sea coal facings.
2, 138¼	pounds soap.
636	gallons soft-soap.
179½	pounds sponge.
16	stoves.
215	parts of stoves.
42	stove fixtures.
23	papers stove polish.
357½	feet stove pipe.
69	pounds stove pipe.
31	stove-pipe elbows.
1, 198	feet steam-pipe covering.
623	papers tripoli.
4	wash stands and fixtures.

MATERIALS FOR OFFICE USE.

14	baskets.
338	sheets blotters.
2	blotter baths.
100	sheets oil-boards.
105	books of reference.
2	book-cases.
4, 875	cards, assorted.
200	sheets card boards.
2	caligraphs.

37	chairs, stools, &c.
2	clocks.
7	composition rollers.
1	desk.
2,000	dials for watch-clock.
93	drawing instruments.
14	pans drawing paint.
4	bottles drawing paint.
20	electrotypes.
77,600	envelopes.
24	erasers.
1	hektograph.
30	pounds hektograph composition.
270	bottles ink.
907	pounds printer's ink.
6	pieces India ink.
6	bottles India ink.
23	ink-stands.
68	pieces India rubber.
1	pound India rubber.
37,500	labels.
3	letter-presses.
86	memorandum blocks.
30	bottles mucilage.
8	mucilage brushes.
8	mucilage stands.
500	order slips.
$280\frac{1}{10}$	reams letter paper.
23,024	sheets paper, assorted.
17	paper fasteners.
9	paper folders.
94	gross pens.
3,367	pencils.
240	pencil and pen holders.
36	pencil-point protectors.
9	boxes pins.
5	bottles pounce.
8	pounce boxes.
7	spools ribbon.
247	gross rubber bands.
83	rubber stamps.
2	rulers.
124	pounds roller composition.
96,500	seals.
181	pounds sealing wax.
16	sponge cups.
7,750	tags
66	yards tape.
4	spools tape.
$\frac{10}{12}$	gross thumb-tacks.
$622\frac{2}{3}$	yards tracing cloth.
1	font type.
1	water-cooler.
156	quill-pens.
30	stencil boards.

LABORATORY STORES.

574	bottles and vials.
19	barometers and thermometers.
3	carboys.
8, 710	corks.
165	crucibles.
19	gauge glasses.
27	glass breakers.
21	glass tubes.
1	hydrometer.
21	jars.
64	level glasses.
120	materials for electric batteries.
1	mortar and pestle.
2	pyrometers.
3	retorts.
32, 114¼	pounds acid.
8¾	gallons acid.
956½	gallons alcohol.
94	pounds alum.
50	pounds ammoniated copper.
72½	pounds antimony
167	pounds aqua ammonia.
202	pounds beeswax.
72	sticks black cement.
152, 128	pounds bone.
85	pounds borax.
42	pounds camphor.
43½	pounds chalk.
50	pounds powdered charcoal.
500	pounds chloride of lime.
10	pounds concentrated lye.
98	boxes concentrated lye.
755	pounds copper and its preparations.
232	pounds electropion fluid.
3, 100¾	pounds glue.
12	gallons glue.
228¼	pounds glycerine.
30	grains gold chloride.
2	packs gold-leaf.
110	pounds ground glass.
25	pounds ground pepper.
27	pounds gum arabic.
20	pounds gum tragacanth.
72	hand grenades.
67	pounds horse medicine.
24	papers horse powders.
2	ounces iodine.
266	pounds iron and its preparations.
218	gallons isinglass.
8	ounces laudanum.
2	bottles linament.
50	pounds manganese and its salts.
400½	pounds mercury and its salts.
167	gallons molasses.

20	pounds nickle-salts.
213¼	reams paper.
32, 295½	pounds paper.
46	rolls paper.
100⅓	yards paper.
7	barrels pitch.
6, 086½	pounds potash, various.
55½	pounds sal-ammoniac.
13, 650	pounds sal-soda.
3	gallons silver solution.
4, 327	pounds silicate of soda.
94½	pounds spirits of niter.
653½	pounds sulphur.
50	pounds sugar of lead.
112	pounds strontia-nitrate.
7, 145	pounds straw-boards.
41	quarts tar.
4, 009	pounds tallow.
20	pounds tobacco.
100	pounds vassaline (anti-corrosive).
20	pounds vermin powder.
25½	gallons whiting.

PAINTS, OILS, &C.

9	barrels asphaltum.
50	pounds asphaltum.
117½	gallons benzine.
4, 380½	gallons coal-tar.
145½	gallons drier.
5	pounds drier.
14, 321½	gallons gasoline.
380	pounds gilder's whiting.
31½	pounds hardwood filler.
696	pounds kalsomine.
51	gallons lacker.
312	pounds lampblack.
20	pounds black lead.
507	pounds red lead.
24, 172½	pounds white lead.
385	pounds litharge.
88	pounds extract of logwood.
463½	gallons naphtha.
22	pounds nut-galls.
5¾	gallons castor-oil.
65	gallons cod-liver oil.
697½	gallons dressing oil.
5, 241⅝	gallons illuminating oil.
4, 359	gallons lubricating oil.
3, 493¼	gallons oil, mixing paints.
6, 822	pounds paint, dry.
10, 775½	pounds paint, in oil.
110½	gallons paint, in oil.
1, 792	gallons petroleum and its products.
28	pounds petroleum and its products.
769¼	pounds putty.

8	gallons shellac.
512	pounds shellac.
1,354½	gallons spirits of turpentine.
21	pounds turpentine.
137	pounds burnt umber.
31	pounds raw umber.
350¼	gallons varnish.
3,693½	pounds whiting.
512	pounds zinc.

MISCELLANEOUS.

97	bags.
34	barrels.
8	baskets.
7,209	pasteboard boxes.
899	packing-boxes.
2,102	tin boxes.
18	gallons browning mixture.
486	tin cans.
1	camera stand.
165	pounds axle grease.
65	boxes axle grease.
3	sets post harness.
200	parts of harness.
4	horses.
4,864	feet hose.
3	hose reels.
5,247	pounds Japan wax.
102	kegs.
5	mirrors.
833¾	pounds packing, various.
1	paint burner.
450	powder canisters, 2 pounds.
450	powder canisters, 5 pounds.
2	rubber aprons.
3	rubber caps.
6	rubber coats.
11	pairs rubber boots.
115	rubber rings.
11¾	pounds rubber rings, &c.
97½	pounds sheet rubber.
163½	feet rubber tubing.
29	pairs magazine slippers.
14	barrels saw-dust.
718	tickets, railroad and street cars.
374	trees, &c.
2	wagons.
470	parts of wagons.
7	whips.
2	gallons wood preservative.
3,000	pounds fertilizers.

MACHINES.

2	band-saws with tables, complete.
1	board-cutting shears.
1	boring machine.

1	cutting machine.
1	cultivator.
1	elevator.
1	emery grinder, with table, complete.
1	field-roller.
3	force-pumps.
1	gas-retort.
1	grinding machine.
2	lathes.
3	lawn-mowers.
2	milling machines.
1	morticing machine.
1	molding machine.
1	newel planer vise.
2	planing machines.
2	paper box machines.
1	paper cutting machine.
1	paper cutting shears.
1	printing press.
1	power hammer.
177	parts of mowing machine.
1,288	parts of machines, various.
1	steam-boiler.
1	steam-engine.
1	sharper head.
1	rheostat.
1	saw bench and counter shaft.
1	steam heating apparatus.

INSPECTING INSTRUMENTS.

1	set gauges.
2	micrometer caliper.
2	plane tables and tripods.
6	prismatic gauges.

TOOLS.

70	awls.
2	axes.
68	bits.
5	braces.
1,411	brushes and sash tools.
145	buckets.
195	carpenters' tools, various.
21	chalk-lines.
27	chisels.
8	chucks.
12	coal-hods.
2	crow-bars.
4	sets dies.
3	dies and stocks.
510	drifts.
267	drills.
4	sets drills.
3,239	files.
37	forks (hay and manure.)
12	gauges.
75,746	pounds grindstones.

1,815	handesl.
5	harrows.
93	hatchets and hammers.
24	hoes.
2	kettles.
74	knives.
100	ladles, 7 inch.
100	ladles, 2½ inch.
3	ladders.
11	steel letters and figures.
10	sets letters and figures.
32	machinists' tools, various.
366	mallets.
66	papers needles.
18	pairs nippers.
522	oil cups and oilers.
98	oil stones.
5	oil tanks.
30	pans.
8	picks.
1	pipe-cutter.
6	planes.
26	plane-irons.
3	plows.
47	punches, assorted.
63	rakes.
163	rasps.
113	rules.
54	saddlers' tools, various.
143	saws.
75	saw blades.
1	platform scale (2,500 lbs).
2	counter scales.
10	screw drivers.
45	scythes.
84	scythe stones.
13	scythe-snaths.
8	sieves and sifters.
38	pairs shears.
138	shovels.
18	smiths' tools, various.
19	spades.
6	steel stamps.
19	sand-stones.
4	sets stencil-plates.
2	sets stencil dies, letters and figures.
7	tape lines.
11	taps and reamers.
5	sets taps and reamers.
5	tinners' tools, various.
5	trowels.
1	truck.
157	utensils, various.
43	wheelbarrows.
65	wrenches.
12	vises.

APPENDIX 3.

Statement of ordnance, ordnance stores, &c., issued to the military establishment, including the national homes for soldiers of the volunteer and regular Army, and exclusive of the militia, during the fiscal year ended June 30, 1885.

CLASS I.

4	Gatling guns, 10-long barrels, caliber .45.
7	3-inch rifled guns.
1	10-pounder Parrott gun.
5	light 12-pounder bronze guns.
1	4.5-inch siege gun.

CLASS II.

1	Gatling gun carriage, caliber .45, short.
3	Gatling gun carriages and limbers.
1	6-pounder gun carriage without limber.
2	6-pounder gun carriages and limbers.
1	3-inch gun carriage without limber.
12	3-inch gun carriages and limbers.
13	12 pounder gun carriages and limbers.
5	30 pounder gun carriages and limbers.
4	4.5-inch siege gun carriages and limbers.
6	8-inch rifled gun carriages and chassis.
1	11 inch rifled gun carriage and chassis.
9	15 inch gun carriages and chassis.
2	3-inch gun caissons and limbers.
1	3.2-inch gun caisson and limber.
3	3.2-inch gun carriage limbers, metallic.
1	ammunition cart.
2	Laidley cavalry forges.
4	Laidley cavalry forge carts.

CLASS III.

74	harness bags.
8	elevating bars.
20	manœuvring bars.
2	manœuvring wrench bars.
8	pinch bars.
12	baskets for mortar implements.
13	iron sponge buckets.
22	wooden sponge buckets.
5	iron tar buckets.
134	gutta percha water buckets.

2	leather water buckets
2	papier-machè water buckets.
2	budge barrels.
1	fuse auger.
6	fuse blocks.
16	fuse cutters.
1	fuse gimlet.
13	fuse mallets.
5	fuse plug reamers.
4	fuse plug wrenches.
1	fuse saw.
12	fuse wrenches.
1	gun cover.
53	gunners' gimlets.
42	gunners' haversacks.
9	gunners' pincers.
20	gunners' pouches.
1	gunners' quadrant.
10	pairs gunners' sleeves.
8	handspikes for 8 inch rifle.
16	handspikes, manœuvring.
30	handspikes, trail.
1	set harness, 2-horses, ammunition cart.
5	sets harness, Laidley cavalry forge.
13	sets harness, 2 lead horses.
13	sets harness, 2-wheel horses.
7	common lanterns.
16	globe lanterns.
42	lanyards.
2	paulins, 6 by 10 feet.
5	paulins, 8 by 10 feet.
2	paulins, 12 by 12 feet.
44	paulins, 12 by 15 feet.
10	pendulum hausses, 3-inch gun.
2	pendulum hausses, 12 pounder gun.
4	pendulum hausse pouches.
2	pendulum hausse seats and covers.
3	plummets.
1	pointing cord.
2	pairs ammunition pouches.
4	powder-measures.
37	priming-wires, field gun.
20	prolonges.
6	rammers and staves.
10	gun scrapers.
4	breech sights, Hotchkiss cannon.
10	breech sights, 3 2-inch gun.
1	breech sight, 4.5 inch gun.
1	breech sight, 8-inch gun.
5	breech sights, 100-pounder gun.
5	breech sights, 200-pounder gun.
6	breech sights, 300 pounder gun.
2	breech sights, mountain howitzer.
2	muzzle sights, mountain howitzer.
5	muzzle sights, 3-inch gun.
6	muzzle sights, 3.2-inch gun.

13	muzzle sights, 8-inch gun.
1	muzzle sight seat.
100	securing stakes.
2	shot carriers.
2	sponge covers, Hotchkiss mountain gun.
37	sponge covers, 3-inch gun.
4	sponge covers, 4.5-inch gun.
9	sponge covers, 12-pounder gun.
4	sponge covers, mountain howitzer.
6	sponges and rammers, 6-pounder gun.
39	sponges and rammers, 3-inch gun.
11	sponges and rammers, 12-pounder gun.
1	sponge and staff, Hotchkiss mountain gun.
6	sponges and staves, 4.5-inch gun.
3	sponges and staves, 8-inch gun.
5	sponges and staves, 15-inch gun.
38	thumbstalls.
15	tompions, 3-inch gun.
6	tompions, 12-pounder gun.
2	tompions, 4.5-inch gun.
4	tompions, 8-inch gun.
15	tompions, 10 inch gun.
3	tompions, 15-inch gun.
9	tow-hooks.
15	tube-pouches.
97	vent covers, field gun.
5	vent covers, siege gun.
29	vent pieces.
12	vent punches.
2	water tubs.
32	wipers for mortars.
12	worms and staves.

IMPLEMENTS FOR GATLING GUN.

4	covers for gun, caliber .50.
4	covers for gun, caliber .45.
3	cam extractors.
1	clamp for worm gear.
4	drifts.
20	feed cases.
12	feed magazines.
2	handspikes.
2	headless shell extractors.
4	lock screw-drivers.
4	small screw-drivers.
4	T screw-drivers.
1	shell driver.
4	wiping rods.
2	adjusting screw wrenches.
4	pin wrenches.
1	rear guide nut wrench.

Classes IV and V.

222	3-inch shot.
20	12-pounder shot.
750	4.2-inch shot.

550	4.5-inch shot.
230	8-inch shot.
100	15-inch shot.
500	1.5-inch shell and cartridge case.
50	2.9-inch shell.
422	3-inch shell.
995	3.2-inch shell.
100	4.2-inch shell.
375	4.5 inch shell.
124	12-pounder shell.
300	8-inch shell.
416	10-inch shell.
50	13-inch shell.
300	3 inch case shot.
182	3.2-inch case shot.
124	12-pounder case shot.
500	3-inch canister.
124	12-pounder canister.

CLASS VI.

2,822	Springfield carbines, caliber .45.
592	Colt's revolvers, caliber .45.
713	Chaffee-Reece magazine rifles, caliber .45.
713	Hotchkiss' magazine rifles, caliber .45.
713	Lee magazine rifles, caliber .45.
100	Springfield cadet rifles, caliber .45.
2,794	Springfield rifles, caliber .45.
1	Springfield rifle, model 1866, caliber .50.
40	Springfield shotguns, No. 20.
1	artillery saber.
357	cavalry sabers.
96	musicians' swords.
89	non-commissioned officers' swords.
207	trowel bayonets.
247	hunting knives.

CLASS VII.

ARTILLERY ACCOUTERMENTS.

11	knapsacks for light battery.

CAVALRY ACCOUTERMENTS.

779	canteens and straps.
1	canteen strap.
40	carbine cartridge pouches.
1,359	carbine slings.
1,033	carbine sling swivels.
159	pistol cartridge pouches.
597	pistol holsters.
200	saber attachments.
2,045	saber belts.
1,947	saber belt plates.
674	saber knots.

INFANTRY ACCOUTERMENTS.

2,925	bayonet scabbards.
1,498	blanket bags.
1,994	blanket bag shoulder straps.
6,058	canteens.
3,071	canteen covers.
5,760	canteen straps.
9	cap pouches.
4,327	cartridge belts.
1,915	cartridge belt plates.
5,789	cartridge boxes.
3,727	clothing bags for recruits.
3,639	clothing bag straps for recruits.
3,014	coat straps.
5,020	forks.
5,189	knives.
5,018	spoons.
69	sliding frogs.
5,088	gun slings.
5,518	haversacks.
6,145	haversack straps.
246	hunting knife scabbards.
1	intrenching tool scabbard.
710	magazine belts for Lee rifle.
4,608	meat cans.
5	revolver belts.
10	sword belts and plates, non-commissioned officers'.
5,302	tin cups.
206	trowel bayonet scabbards.
51	waist belts and plates, musicians' and non-commissioned officers'.
4,072	waist belts, privates'.
3,753	waist belt plates, privates'.

APPENDAGES.

45	brushes and thongs.
25	bullet molds.
22	field cases for shot gun supplies.
1	powder charger.
13,079	headless shell extractors.
1,610	jointed ramrods.
21	shot gun outfits.
352	screw-drivers.
5,488	screw-drivers, combination, model 1879.
373	screw-drivers, revolver.
493	screw-drivers, Lee rifle.
180	spring vises.
670	tumbler punches.
713	wiping brushes, Lee rifle.
38	wiping rods, shot gun.
9,969	wiping rods, wood, carbine and rifle.

HORSE EQUIPMENTS.

3,861	curb bridles.
673	watering bridles.

290	carbine sockets and straps.
287	cinchas or hair girths.
2,070	curry-combs.
99	cruppers.
180	forage sacks.
8	girths.
1,435	halters and straps.
4,218	horse brushes.
249	horse covers with surcingles attached.
1,138	lariats.
483	links.
3,118	nose-bags.
1,152	picket pins.
549	saddles, cavalry.
78	saddle bags, canvas.
296	saddle bags, leather.
2,833	saddle blankets, gray.
129	saddle blankets, red.
10	saddle cloths, felt.
55	saddle cloths, hair.
467	side lines.
46	spurs and straps, Mill's pattern.
1,298	spurs.
2,075	spur straps.
341	stirrups.
3	stirrups with guidon sockets.
627	stirrup straps.
1,257	surcingles.
2	sweat leathers.

CLASS VIII.

SMALL-ARM AMMUNITION.

1,229,295	carbine ball cartridges, caliber .45.
527,010	revolver ball cartridges, caliber .45.
125,000	revolver blank cartridges, caliber .45.
4,016 140	rifle ball cartridges, caliber .45.
50	rifle ball cartridges, caliber .50.
523,000	rifle blank cartridges, caliber .45.
1,000	Gatling ball cartridges, caliber 1-inch.
600	Gatling canister cartridges, caliber 1-inch.
2,160,670	round balls, caliber .45.
883,000	carbine bullets, caliber .45.
259,000	revolver bullets, caliber .45.
5,735,000	rifle bullets, caliber .45.
11,551,500	cartridge primers.
1,000	cartridge shells.
9,175	shot-gun cartridge shells.
10,175	pounds shot.
2,007,500	carbine cartridge wads.
409,000	shot-gun cartridge wads.

AMMUNITION FOR CANNON.

6,760	blank cartridges, ½-pound charge.
1,230	blank cartridges, 1-pound charge.
1,000	blank cartridges, 2-pounds charge.

5,563	blank cartridges, 6-pounder gun.
29,574	blank cartridges, 3 inch gun.
560	blank cartridges, 3.2-inch gun.
24,020	blank cartridges, light 12-pounder gun.
300	blank cartridges, heavy 12-pounder gun.
5,500	blank cartridges, mountain howitzer.
463	metallic fuses.
1,000	paper fuses.
1,100	wooden fuses.
17,800	pounds cannon powder.
16,250	pounds hexagonal powder.
500	pounds mealed powder.
31,800	pounds mortar powder.
108,616½	pounds rifle powder.
4,020	electric primers.
145,831	friction primers.

CLASS IX.

264	portable arm racks.
373	assorted blocks.
22,451	marksman's buttons.
2	capstans.
8	capstan bars.
1	hand cart.
1	implement and tool cart.
1	sling cart.
8	sling chains.
1	chronograph.
76	assorted chocks.
2	gun collars.
1	cradle.
10	cranes.
3,735	sharpshooters' crosses.
39	disks.
1	fall, watch tackle.
440	signal flags.
2	casemate gins.
1	field and siege gin.
2	garrison gins.
6	gin-falls.
14	gin-handspikes.
3	gin-slings.
2	gun-lifts.
11	hydraulic jacks.
61	intrenching tools.
60	intrenching-tool carriers.
10	iron pegs, 4 feet long.
9,409	marksmen's pins.
1	plane table.
2	plane tables and tripods with aledades and compasses.
9	gun platforms.
2	mortar platforms.
2	pry-planks.
12	assorted rollers.
48	shifting-planks.

162	shot-marks.
1	sighting-tripod.
38	skids.
90	skidding pieces.
4	cannon slings.
1	stadium.
1	stadia-bag.
336	streamers.
2	Brinton's targets.
12	Cushing's targets.
4	Cushing's target axles.
8	Cushing's target caps.
30	Cushing's target truck frames.
8	Cushing's target truck wheels.
230	Laidley's targets.
32	Laidley's target axles.
3	Laidley's target axles with pins and wedges.
8	Laidley's target axle boxes and pins.
8	Laidley's target center blocks and pins.
33, 750	Laidley's target centers.
24	Laidley's target clamps.
334	Laidley's target cross-pieces.
1, 669	Laidley's target frames.
28	Laidley's target journal-boxes.
76	Laidley's target nave-boxes.
40	target levers.
20	target lever-boxes.
14, 536, 500	target pasters.
139	target plates.
67	target rails.
334	target uprights.
2	Lancaster targets.
73, 137	paper targets.
12	rolling targets.
1	sliding target.
6	trace ropes.
2	casemate trucks.
2	trunnion loops.
2	trunnion rings.
89	pairs eccentric trunnion rings.
12	hydraulic jack valves.
1	wagon-sling.

RELOADING TOOLS, &C.

1	set bench reloading tools.
74	sets hand reloading tools.
150	combination anvils.
5	ball-molds (4-balls).
96	brush wipers.
9	brush wipers for shotgun cartridges.
17	adjustable powder chargers.
33	adjustable powder and shot chargers.
46	bench chargers for hand reloading tools.
2	crimping dies.
8	crimping die caps.

22	crimping and reloading dies for revolver cartridges.
110	crimping and reloading dies for rifle cartridges.
5	reloading dies.
24	resizing dies for revolver cartridge shells.
192	resizing dies for rifle cartridge shells.
81	drifts.
9	drifts for shotgun cartridge shells.
6	primer extractors.
213	extractor pins.
70	funnels.
7	funnels for shotgun cartridges.
50	ladles.
103	mallets.
7	powder measures.
6	oil cans.
37	oil cups.
115	priming tools for shotgun cartridges.
36	priming tools for rifle cartridges.
312	priming-tool pins.
2	priming-tool spindle screws.
1	primer punch.
26	reloading punches for revolver cartridges.
136	reloading punches for rifle cartridges.
173	resizing punches.
6	safety sockets.
67	shell scrapers.
1	strainer.
3	washers.
23	wiping-rods.

CLASS X.

PARTS OF CLASS II.

3	cap square chains.
1	cap square key.
3	cheek bolts.
3	cylinder straps for carriage.
1	elevating fulcrum.
9	elevating screws.
2	foot boards, caisson.
6	foot boards, limber.
10	forks for field limber.
8	hounds.
1	nave for cavalry forge.
16	poles for field gun.
1	pole for mortar wagon.
8	pole lifts.
3	pole yokes.
4	rails.
1	shaft for cavalry forge.
8	shoes for artillery wheels.
8	splinter bars.
2	stocks for caisson.
32	washers.
19	wheels for field carriages.

PARTS OF CLASS III.

8	artillery curb bits.
6	breast straps.
1	breechings.
4	artillery bridles.
455	brass plated buckles.
646	iron roller buckles.
87	collars.
20	collar pads.
120	artillery halters.
32	artillery halter chains.
440	artillery halter straps.
1½	pairs hames.
12	hame clasps with chains and toggles.
4	leg guards.
6	brass loops.
27	pole pads.
86	pole straps.
4	rammer heads.
148	rosettes for artillery bridles.
1	driver's saddle.
1	valise saddle.
303	woolen sponges.
20	sponge heads.
16	staples for valise saddle.
2	staves.
13	lead traces.
12	patent splinter bar traces.
7	wheel traces.
100	whips.

PARTS OF CLASS V.

100	bushings for shell.
900	copper bands for shell.
1,100	brass fuse plugs.
500	tin straps.

PARTS OF CLASS VI—PARTS OF SPRINGFIELD CARBINE.

61	bands.
6	butt-plates.
228	front sights.
4,011	front-sight covers.
12	front-sight cover springs.
12	front-sight cover spring screws.
12	front-sight cover friction springs.
148	rear sights.
51	rear-sight bases.
48	rear-sight base screws.
382	rear-sight leaves.
779	stocks, wood part.
102	swivels.

PARTS OF SPRINGFIELD RIFLE.

16	lower bands.
26	upper bands.

276	band springs.
2	barrels.
11	bayonets.
98	bayonet clasps.
128	bayonet-clasp screws.
468	breech-block caps.
495	breech-block cap screws.
50	breech screws.
1,293	bridles.
990	bridle screws.
106	butt plates.
212	butt-plate screws.
981	cam-latch springs.
2,041	ejector springs.
1,747	ejector spring spindles.
408	ejector studs.
4,511	extractors.
5,912	firing pins.
932	firing-pin screws.
304	firing-pin springs.
248	front sights.
8,861	front-sight covers.
116	front-sight pins.
218	guard-bow nuts.
24	guard-bow swivels.
54	guard-bow swivel screws.
120	guard plates.
430	guard screws.
442	hammers.
6,003	hinge pins.
10	hinge-pin studs.
68	locks.
121	lock plates.
699	main springs.
400	main-spring swivels.
423	main-spring swivel rivets.
3,794	pistol grips, metal.
14	pistol grips, wood.
269	pistol-grip screws.
353	ramrods.
374	ramrod stops.
501	rear sights.
53	rear-sight bases.
852	rear-sight base screws.
39	rear-sight base springs.
498	rear-sight leaves.
1,149	rear-sight plates, buckhorn.
56	rear-sight joint pins.
120	rear-sight slides.
41	rear-sight slide blocks.
700	rear-sight slide gibs.
151	rear-sight slide plates.
201	rear-sight slide screws.
88	rear-sight slide springs.
1,655	sears.
962	sear screws.

522	sear springs.
514	sear-spring screws.
858	side screws.
161	side-screw washers.
1,179	stocks, wood part.
723	tang screws.
256	thumb pieces.
107	stock tips.
117	tip screws.
9,006	triggers.
1,198	trigger screws.
1,917	tumblers.
1,525	tumblers, swiveled.
504	tumbler screws.

PARTS OF CHAFFEE-REECE MAGAZINE RIFLE.

1	bolt.
1	cartridge lifting spring.
10	ejector springs.
10	extractors.
10	firing pins.
20	main springs.

PARTS OF HOTCHKISS CARBINE AND RIFLE.

2	butt stocks.
6	cut off springs.
512	extractors.
10	firing pins.
512	main springs.
20	side screws.
20	stocks, wood part, carbine.
11	tang screws.

PARTS OF LEE'S MAGAZINE RIFLE.

107	extractors.
102	extractor springs.
107	firing pins.
3,937	magazines.
502	magazine springs.
117	main springs.
10	sears.
107	sear springs.
10	side-spring screws.
10	tang screws.
10	triggers.

PARTS OF BREECH-LOADING SHOTGUN.

3	barrels and receivers.
19	extractors.
10	front sights.
1	hammer.
2	stocks, wood part.

PARTS OF COLT'S REVOLVER.

112	back-strap screws.
2	bolts.
42	bolt screws.
335	center pins.
312	center-pin bushings.
365	center-pin catch screws.
39	center-pin screws.
131	ejector heads.
151	ejector rods.
75	ejector springs.
3	ejector tubes.
42	ejector-tube screws.
39	firing pins.
35	firing-pin rivets.
51	gates.
32	gate catch screws.
33	gate springs.
58	guard screws, long.
50	guard screws, short.
168	hammers.
115	hammer cams.
4	hammer rolls.
4	hammer-roll rivets.
54	hammer screws.
195	hands.
65	hand springs.
153	main springs.
51	main-spring screws.
29	sear springs.
19	sear-spring screws.
17	sear and stop-bolt screws.
114	sear and stop-bolt springs.
67	sear and stop-bolt spring screws.
175	triggers.
61	trigger screws.

PARTS OF SCHOFIELD'S, SMITH & WESSON REVOLVERS.

10	escutcheon nuts.
10	escutcheon studs.
35	hammers.
10	lifters.
10	main-spring swivels.
60	triggers.
60	trigger pins.
10	trigger-spring pins.

PARTS OF SWORDS.

7	musicians' steel scabbards.
3	officers' browned scabbards.

PARTS OF CLASS VII.

30	bridle headstalls.
100	bridle ornaments.
80	bridle reins.

7,207	brass bar buckles.
2,725	brass wire buckles.
1,524	iron bar buckles.
755	iron roller buckles.
352	cincha straps.
164	coat straps.
60	curb straps.
41	gross brass escutcheon pins.
540	halter bolts.
10	halter chains.
704	halter headstalls.
2,922	halter rings.
62	halter-ring swivels.
528	halter squares.
2,161	halter straps.
2,333	halter-hitching straps.
70	brass hooks with rivets.
70	brass wire hooks.
896	double-spring lariat hooks.
923	saber-snap hooks.
1,880	ovals.
1,208	brass rings.
174	iron D rings.
1,926	iron rings.
100	saber-belt loops.
120	saber-belt slides with hooks and rings.
100	saber-belt studs.
462	saddle nails, Japanned.
400	saddle-bag studs.
1	screw for ball molds.
300	shields.
209	side line fasteners.
3,080	brass foot staples.
2,624	brass staples for rings.
80	leather lacing thongs.
672¼	yards webbing, 4 inches wide.
24	yards webbing, 4.5 inches wide.
42	yards webbing, 7.5 inches wide.

PARTS OF CLASS VIII.

1,352	cartridge bags, ½-pound charge.
20	cartridge bags, 1-pound charge.
520	cartridge bags, 2-pounds charge.
1,000	cartridge bags, 6-pounder gun.
6,200	cartridge bags, 12-pounder gun.
2,500	cartridge bags, 20-pounder gun.
1,650	cartridge bags, 30-pounder gun.
800	cartridge bags, 100-pounder gun.
7,100	cartridge bags, 3-inch rifled gun.
300	cartridge bags, 3.2-inch breech-loading gun.
1,200	cartridge bags, 4.5-inch siege gun.
200	cartridge bags, 8 inch rifled gun.
730	cartridge bags, 10-inch gun.
500	cartridge bags, 13-inch gun.
50	cartridge bags, 15-inch gun.

PARTS OF CLASS IX.

7	pointing plummets for siege mortar.
12	pointing trestles for siege mortar.
2	poles for sling cart.

PART SECOND: CLOTH, ROPE, THREAD, &C.

102	yards burlaps.
50	feet card clothing.
13,998 11/12	yards cotton cloth.
23½	pounds lanyard cord.
10	pieces sash cord.
259	pounds sash cord.
50	pounds waste cotton.
3	yards cotton duck.
5	pounds curled hair.
202	pounds marline.
350	feet rope.
5,218¾	pounds rope.
218½	pounds linen thread.
337	pounds shoe thread.
320	pounds tow.
277½	pounds twine.
79¾	pounds yarn.

IRONMONGERY.

24	bolts and nuts.
4	brass boxes.
13⅝	pounds sheet brass.
10	papers iron brads.
50	pairs brass butts.
24	pairs iron butts.
6	brass cocks.
2	books.
12,656	horseshoes.
2,687	pounds horseshoes.
988	pounds bar iron.
105	pounds sheet iron.
4	iron ladles.
20	cold shut links.
820	pounds horseshoe nails.
2,666	pounds iron nails.
592	padlocks.
4	padlock keys.
12	cast-iron posts.
137	pounds brass rivets and burrs.
794½	pounds copper rivets and burrs.
103	pounds iron rivets and burrs.
109	gross screw pins.
132 2/9	gross brass screws.
179	gross iron screws.
24	iron snaps.
101	pounds solder.
425	pounds spikes.
276⅛	pounds bar steel.

20½	feet steel wire rope.
8	steel straps.
6,000	copper tacks.
45	papers copper tacks.
80¾	pounds copper tacks.
1,291,000	iron tacks.
1,085	papers iron tacks.
115¼	pounds iron tacks.
6	iron thimbles.
1	box sheet tin.
395½	pounds sheet zinc.

LEATHER, &C.

1,008	sides bridle leather.
196	pounds collar leather.
24,798⅜	pounds harness leather.
2	sides lacing leather.
156	quarts leather blacking.
164	pounds ingredients for leather blacking.
247	pounds blackwax.
507	ounces bristles.

LUMBER, &C.

9,650	feet boards.
2,495	feet plank.
2,532	feet scantling.
10	barrels cement.

CLEANING, HEATING, &C.

54	Bath bricks.
207	corn brooms.
20	counter dusting brushes.
5	feather dusting brushes.
23	button brushes.
10	wire scratch brushes.
15	button-sticks.
33	pounds candles.
217	chamois skins.
43	boxes cleaning material.
11,850	pounds coal.
58½	quires crocus cloth.
1,160	quires emery cloth.
168	quires emery paper.
122⅛	pounds polishing material.
92½	pounds scouring material.
10	pounds pumice stone.
655	pounds rotten stone.
135	quires sand paper.
185	pounds bar soap.
2,949	pounds castile soap.
197	pounds sponge.
862	papers tripoli.

MATERIAL FOR OFFICE USE.

4	half-boxes blacking for stencil outfit.
173	instruction books.

8	fitch brushes.
2	boxes chalk crayons.
10	marking outfits.
5	quires drawing paper.
30	pounds log paper.
1	safe.
3	seal stamps.
13	pounds sealing wax.
6	sets stencil dies or plates, letters and figures.
78	sets stencil outfits.
180	metallic tags.
2,000	shipping tags.

LABORATORY STORES.

125	gallons alcohol.
121¾	pounds beeswax.
25	pounds borax.
30	pounds camphor.
2	pounds chalk.
50	pounds pulverized charcoal.
50	pounds ammoniated copper.
1	barrel flour.
80	pounds glue.
1,511	pounds laboratory paper.
25	pounds black pepper.
336	pounds chlorate of potash.
112	pounds nitrate of strontia.
350	pounds sulphur.
120	pounds tallow.
20	pounds tobacco.
10	pounds vaseline.
975	pounds Japan wax.
25½	gallons whisky.

OILS, PAINTS, &C.

50	pounds asphaltum.
3	gallons benzole.
1	barrel coal tar.
172	gallons coal tar.
51¾	gallons Japan drier.
25	pounds patent drier.
146	gallons lacker.
45	pounds lampblack.
190	pounds red lead.
1,735	pounds white lead.
17	pounds extract logwood.
225	quarts cosmoline oil.
3,972	pounds harness oil.
239½	gallons kerosene oil.
5	gallons lard oil.
671½	gallons linseed oil.
2¾	gallons lubricating oil.
158	gallons neatsfoot oil.
68½	gallons neutral oil.

747¾	gallons sperm oil.
962	pounds black paint.
10	pounds ivory black paint.
20	pounds Prussian blue paint.
2,209	pounds brown paint.
35	pounds green paint.
490	pounds lead-color paint.
1,740	pounds metallic paint.
2,703	pounds olive paint.
35	pounds Venetian red paint.
30	pounds vermilion paint.
157	pounds putty.
35	pounds shellac.
754	gallons turpentine.
50	pounds umber.
2½	gallons asphalt varnish.
3	gallons coach varnish.
31	gallons copal varnish.
2	gallons gear varnish.
27½	gallons Japan varnish.
243	pounds whiting.

MISCELLANEOUS.

468	arm chests.
200	cotton powder bags.
26	metallic powder barrels.
2,169	wooden powder barrels.
4	bottoms for reloading-tool boxes.
28	reloading-tool boxes.
1	cleaning material box.
2,070	powder canisters.
107	tin cans.
1	instrument case.
1	case for sample equipments.
20	chamois-skin saber cases.
20	chamois-skin sword cases.
1	demijohn.
360	pounds grease for gun bore.
460	pounds wheel grease.
60	pounds gutta-percha.
258	halyards with screw-eyes.
75	feet rubber hose.
76	powder kegs.
20	pounds flax packing.
142	feet rubber packing.
1	singletree.

MACHINES AND PARTS OF MACHINES.

1	diameter calipers.
136	crusher gauge cylinders.
1	lathe chuck.
936	pressure disks.
4	crusher gauges.
1	expansion caliber gauge.
1	fuze-thread gauge.

2	pressure gauges.
6	ring gauges.
4	ring gauges for star gauge.
2	star gauges.
1	wire inspecting instrument.
1	foot lathe.
8	measuring points for star gauge.
3	sets measuring points for star gauge.
1	lathe rest.
8	measuring rods, adjustable.
1	pressure scales.

TOOLS.

50	aprons.
135	awl handles.
14	patent awl handles.
261	saddlers' awls.
1	seat awl.
220	stitching awls.
3	stub awls.
34	ax handles.
12	felling axes.
1	hand ax.
15	armorers' bits.
6	auger bits.
32	bits for brace.
1	set of bits.
1	copper boiler.
2	braces.
221	paint brushes.
6	paste brushes.
231	sash brushes.
3	stencil brushes.
2	varnish brushes.
10	iron buckets.
22	wooden buckets.
2	calipers.
20	chalk-lines.
37	chisels.
11	saddlers' clamps.
23	claw-tools.
2	clenching irons.
38	compasses.
2	iron creasers.
31	wooden creasers.
10	dies.
2	die-stocks.
11	dust pans.
31	edge tools.
119	file handles.
668	files.
10	rocket formers.
5	copper funnels.
20	gouges.
2	grindstones, with arbors and cranks.
165	assorted hammers.
3	sledge hammers.

11	hatchets.
11	saddlers' horses.
2	jackscrews.
322	assorted knives.
10	gauge knives.
9	splitting knives.
41	mallets.
2	mauls.
10	measures.
2	nail extractors.
26	nail punches and clinch knives.
1, 765	assorted needles.
45	papers needles.
82	nippers.
3	oil cans.
18	oil droppers.
11	oilers.
4	oil stones.
9	pickax handles.
7	pickaxs, handled.
37	pincers.
12	pins for surveyors' chains.
6	plane-irons.
8	planes.
11	pliers.
5	pricking carriages.
20	pricking wheels.
3	pritchels.
84	assorted punches.
31	spring punches.
2	punching blocks.
3	rakes.
379	rasps.
2	reamers.
1	riveting iron.
10	rivet sets.
41	rules.
21	sandstones.
13	saws.
9	saw blades.
1	scales.
26	scissors.
2	scrapers.
2	scoops.
27	screw-drivers.
2	screw-taps.
3	scythes.
2	scythe snaths.
8	scythe stones.
30	shears.
6	pairs rubber shoes.
30	shovels.
5	seives.
4	slickers.
27	pairs magazine slippers.
1	tinners' snips.

4	spades.
2	spatulas.
10	squares.
2	strainers.
6	taps.
3	machine taps.
4	tape lines or measures.
37	thimbles.
2	templets.
3	ticklers.
3	tongs.
1	tool-bag for saddlers' and smiths' tools.
6	tool-handles.
7	vises.
1	watering pot.
8	wheelbarrows.
47	wrenches.

APPENDIX 4.

Apportionment of ordnance, ordnance stores, &c., for the fiscal year ending June 30, 1885, *under sections* 1661 *and* 1667, *Revised Statutes United States, and regulations established in conformity therewith.*

States and Territories.	Number of Senators and Representatives.	Money-value.
Alabama	10	$4,640 37
Arkansas	7	3,248 26
California	8	3,712 30
Colorado	3	1,392 11
Connecticut	6	2,784 22
Delaware	3	1,392 11
Florida	4	1,856 15
Georgia	12	5,568 45
Illinois	22	10,208 82
Indiana	15	6,960 56
Iowa	13	6,032 48
Kansas	9	4,176 34
Kentucky	13	6,032 48
Louisiana	8	3,712 30
Maine	6	2,748 22
Maryland	8	3,712 30
Massachusetts	14	6,496 52
Michigan	13	6,032 48
Minnesota	7	3,248 26
Mississippi	9	4,176 34
Missouri	16	7,424 59
Nebraska	5	2,320 19
Nevada	3	1,392 11
New Hampshire	4	1,856 15
New Jersey	9	4,176 34
New York	36	16,705 33
North Carolina	11	5,104 41
Ohio	23	10,672 85
Oregon	3	1,392 11
Pennsylvania	30	13,921 10
Rhode Island	4	1,856 15
South Carolina	9	4,176 34
Tennessee	12	5,568 45
Texas	13	6,032 48
Vermont	4	1,856 15
Virginia	12	5,568 45
West Virginia	6	2,784 22
Wisconsin	11	5,104 41
Arizona Territory*	3	1,392 11
Dakota Territory*	3	1,392 11
Idaho Territory*	3	1,392 11
New Mexico Territory*	3	1,392 11
Montana Territory*	3	1,392 11
Utah Territory*	3	1,392 11
Washington Territory*	3	1,392 11
Wyoming Territory*	3	1,392 11
District of Columbia*	3	1,392 11
Total	428	200,000 00

* Apportionment according to the first paragraph of the President's regulation of April 30, 1855.

APPENDIX 5.

Statement of ordnance, ordnance stores, &c., distributed to the militia from July* 1, 1884, *to June* 30, 1885, *under sections* 1661 *and* 1667, *Revised Statutes United States.

Class I.

2	3-inch wrought iron rifled guns.
9	Gatling guns, 10 barrels, long, caliber .45.

Class II.

2	carriages and limbers for 3-inch guns.
6	metallic carriages and limbers for Gatling gun, caliber .45.
3	carriages and limbers for Gatling gun, caliber .45.

Class III.

2	fuze cutters.
25	fuze gouges.
2	fuze-plug wrenches.
2	fuze wrenches.
2	gun covers, Gatling gun.
39	gunners' haversacks.
31	gunners' gimlets.
6	gunners' pincers.
26	handspikes, trail.
24	harness sacks.
107	lanyards.
2	muzzle sights for light 12-pounder gun.
2	muzzle sights for 3-inch rifle.
106	priming wires.
35	prolonges.
4	poles for 3-inch carriage.
70	pole pads.
14	pair pole straps.
29	paulins, 12 by 15 feet.
8	pendulum hausses.
4	pendulum-hausse seats.
4	pendulum-hausse pouches.
13	sets artillery harness, 2 horses, wheel.
4	sets artillery harness, 2 horses, lead.
12	sponge buckets, iron.
35	sponges and rammers, 12-pounder gun.
6	sponges and rammers, 12-pounder mountain howitzer.
50	sponges and rammers, 6-pounder gun.
57	sponges and rammers, 3-inch gun.
29	sponge covers, 12-pounder gun.

50	sponge covers, 6-pounder gun.
33	sponge covers, 3-inch gun.
4	sponges, woolen, 12-pounder gun.
4	sponges, woolen, 3-inch gun.
107	thumbstalls.
4	tar buckets, iron.
18	tube pouches.
6	tow hooks.
4	tompions.
45	vent covers.
6	vent punches.
4	wheels, No. 1.
6	watering buckets.
5	worms and staves.

CLASSES IV AND V.

100	10-pounder solid shot, fully prepared.
20	3-inch Hotchkiss shell, percussion fuze.
250	3-inch Hotchkiss shell, time fuze.
10	3-inch canister.
24	10-inch shell, fully prepared.
30	10-inch mortar shell.
100	6-pounder canister shot.

CLASS VI.

2,640	Springfield rifles, caliber .45.
160	Springfield "cadet" rifles, caliber .45.
100	Springfield "cadet" rifled muskets, caliber .58, C. & R.
80	Springfield rifled muskets, caliber .58, C. & R.
436	Springfield carbines, caliber .45.
83	Colt's revolvers, caliber .45.
85	officers' swords.
133	non-commissioned officers' swords.
120	sabers, light cavalry.
90	sabers, light artillery.
880	bayonets.

CLASS VII.

APPENDAGES.

700	combination screw drivers.
115	headless shell extractors.

HORSE EQUIPMENTS.

25	bridles, curb, cavalry.
150	halters.
25	pairs spurs and straps.
25	saddles, cavalry.
2,665	saddle blankets.
10	saddle cloths.

INFANTRY EQUIPMENTS.

3,609	bayonet scabbards.
2,790	blanket bags.

2,790	pairs blanket bag shoulder straps.
2,690	pairs coat straps.
50	cap pouches and picks.
2,051	canteens and straps.
190	cartridge belts and plates.
4,549	cartridge boxes.
50	cartridge-box belts and plates.
100	carbine cartridge boxes.
3,519	gun slings.
151	haversacks.
300	waist belts.
5,479	waist belts and plates.
350	waist-belt plates.
100	sets infantry equipments, caliber .58.
121	meat cans.
201	knives.
201	forks.
201	spoons.
201	tin cups.

ARTILLERY EQUIPMENTS.

12	leg guards.
24	linch pins, No. 1.
24	linch washers, No. 1.
10	sets stay pins.

CAVALRY EQUIPMENTS.

200	carbine slings.
475	carbine sling swivels.
159	pistol holsters.
4	revolver belts.
230	saber belts and plates.
1	saber knot.
181	non-commissioned officers' sword belts and plates.

CLASS VIII.

1,200	blank cartridges, 12-pounder mountain howitzer.
600	blank cartridges, 6 pounder gun.
3,100	blank cartridges, 3-inch rifle.
688,000	rifle ball cartridges, caliber .50.
460,000	rifle ball cartridges, caliber .45.
62,700	rifle blank cartridges, caliber .50.
165,300	rifle blank cartridges, caliber .45.
6,000	revolver ball cartridges, caliber .45.
32,750	friction primers.
115,000	cartridge primers.
21,000	rifle shells, primed.
110,000	rifle bullets, lubricated.
1,000	pounds powder.

MISCELLANEOUS.

28	sets reloading tools.
2	sets dies, caliber .45, 500-grain bullets.
220	wiping rods, wooden.

4	wiping rods, Gatling gun.
5	jointed ramrods, steel.
150	cartridge bags, 12-pounder gun.
1	lock screw-driver, for Gatling gun.
4	small screw-drivers, for Gatling gun.
1	pin wrench, for Gatling gun.
2	pointing rings and plates, 3-inch carriage.
12	linch pins, 3-inch carriage.
320	paper targets.
66	boxes cleaning materials.
5	arm chests.

PARTS OF SPRINGFIELD RIFLE, CALIBER .45.

21	barrels.
10	band swivels.
12	band swivel pins.
300	bayonet clasps.
320	bayonet clasp screws.
5	breech blocks.
54	breech-block caps.
64	breech-block cap screws.
10	bridles.
10	bridle screws.
17	butt plates.
34	butt-plate screws.
65	cam latches.
280	cam-latch springs.
280	ejector springs.
230	ejector-spring spindles.
12	ejector studs.
230	extractors.
3, 525	firing pins.
20	firing-pin screws.
300	firing pin springs.
36	guard bows.
30	guard bow swivels.
160	guard-bow swivel screws.
12	guard screws.
130	hammers.
25	hinge pins.
10	lower bands.
5	lock plates (assembled).
85	main springs.
20	main-spring swivels.
994	rear sights.
60	rear-sight screws.
1, 200	rear-sight base screws.
127	ramrods.
29	ramrod stops.
210	sears.
215	sear springs.
175	sear-spring screws.
50	sear screws.
178	side screws.
50	side-screw washers

30	spring vises.
120	stocks.
402	tumblers.
20	tumbler punches.
362	tumbler screws.
78	tang screws.
20	thumb pieces.
6	triggers.
20	upper bands.
45	upper-band swivels.

PARTS OF SPRINGFIELD RIFLES, CALIBER .50.

200	bridles.
200	bridle screws.
52	breech screws.
200	breech-block cap screws.
62	bayonet clasps.
62	bayonet-clasp screws.
12	cam latches.
300	cam-latch springs.
100	extractors.
200	ejector springs.
200	ejector-spring spindles.
1,450	firing pins.
100	firing-pin screws.
4	guard bows.
8	guard-bow swivels.
8	guard-bow swivel screws.
10	hammers.
100	hinge pins.
50	lower bands.
200	lower-band screws.
615	rear sights.
16	rear-sight leaf slides.
10	rear-sight leaf screws.
500	rear-sight base screws.
200	rear-sight springs.
105	ramrods.
4	sears.
4	sear screws.
36	stocks.
200	tang screws.
2	thumb pieces.
2	thumb-piece screws.
108	tumblers.
112	tumbler screws.
1	stock tip.
1	tip screw.
100	upper bands.
4	upper-band swivels.
404	upper-band swivel screws.

APPENDIX 6.

Statement of ordnance, ordnance stores, &c., distributed to the Territories and States bordering thereon, from July 1, 1884, *to June* 30, 1885, *under the joint resolutions of July* 3, 1876, *March* 3, 1877, *and June* 7, 1878, *and the act of May* 16, 1878.

1, 750	Springfield rifles, caliber .50.
27, 500	rifle-ball cartridges, caliber .50.

APPENDIX 7.

***tatement** of ordnance and ordnance stores, &c., distributed to colleges from July 1, 1884, to June 30, 1885, under section 1225, Revised Statutes United States, as amended by act approved July 5, 1876.*

CLASS I.

10	3-inch wrought-iron rifled guns, model 1861.

CLASS II.

2	carriages and limbers for light 12-pounder gun.
10	carriages and limbers for 3-inch guns.

CLASS III.

12	gunners' haversacks.
10	handspikes, trail.
24	lanyards.
12	priming wires.
8	paulins, 12 by 15 feet.
5	pendulum hausses.
5	pendulum-hausse seats.
5	pendulum-hausse pouches.
4	sponges and rammers for 12-pounder gun.
20	sponges and rammers for 3-inch rifled guns.
4	sponge covers for 12-pounder gun.
20	sponge covers for 3-inch rifled guns.
12	tompions.
24	thumbstalls.
12	tube-pouches.
12	vent covers.

CLASS VI.

80	Springfield rifles, caliber .45.
990	Springfield cadet rifles, caliber .45.
38	non-commissioned officer's swords.

CLASS VII.

920	bayonet scabbards.
920	cartridge boxes.
920	waist belts and plates.

16	waist belts and plates, N. C. O.
16	sliding frogs, N. C. O. waist belts.
22	shoulder belts and plates, N. C. O.

CLASS VIII.

200	blank cartridges for 12-pounder gun.
500	blank cartridges for 10-pounder gun.
650	blank cartridges for 6-pounder gun.
1,100	blank cartridges for 3-inch gun.
1,000	rifle blank cartridges, caliber .50.
2,000	carbine blank cartridges, caliber .50.
29,000	carbine blank cartridges, caliber .45.
27,500	carbine ball cartridges, caliber .45.
7,400	friction primers.

APPENDIX 8.

Report of action taken under the act of March 3, 1881, *during the fiscal year ended June* 30, 1885.

SOLD.

To F. H. Smith.

1884.		
Nov. 1.	500 pounds mortar powder from broken-up ammunition, at 8 cents per pound	$40 00
1885.		
May 26.	400 pounds mortar powder from broken up ammunition, at 8 cents per pound	32 00
	Total proceeds..	72 00

PURCHASED.

From E. I. Du Pont de Nemours & Co.

1884.		
July 7.	100 pounds hexagonal powder, at 25 cents per pound	$25 00
Nov. 24.	200 pounds square powder, at 25 cents per pound	50 00

From B. B. Hotchkiss.

Nov. 24.	6,225 pounds brown prismatic powder, at $45\frac{52}{100}$ cents per pound..	2,833 76
	Total purchased..	2,908 76

APPENDIX 9.

REPORT OF THE ORDNANCE BOARD ON TEST OF 6-INCH SHELLS FIRED BY THE DYNAMITE PROJECTILE COMPANY.

(1 plate.)

A letter from the Chief of Ordnance, dated Washington, January 29, 1884, was presented to the Board by Mr. F. H. Snyder, General Manager of the Dynamite Projectile Company. The letter stated that Mr Snyder might desire to borrow a gun to make experiments with, and stated further that the subject was important and should receive careful attention and consideration. After an interview with Mr. Snyder the Board wrote to the Chief of Ordnance recommending that a light 12-pounder bronze gun should be loaned by the Government in order that preliminary experiments might be made. This recommendation was approved.

May 15, 1884, Mr. Snyder wrote to the Board requesting that he might be furnished with two 6-inch guns for experimental use at Sandy Hook in firing shells and water projectiles charged with dynamite, indicating a Moffatt 6-inch breech-loading rifle and a 24-pounder smoothbore gun, bored up to 6 inches, as the pieces he would prefer. He further requested that he might be permitted to use, when not otherwise engaged, some of the shop tools at Sandy Hook for fitting and repairs of shells after trial. The Board favorably recommended all these requests, stipulating, however, that the 24-pounder gun should be bored up from 5.82 to 6 inches, at the expense of the Dynamite Projectile Company, and the recommendation was approved by the Chief of Ordnance.

The guns used in the trials were those above referred to. As they were in no respects subjects of trial, no description of them is given.

The powder was of the E. V. M. type, density 1.750, granulation 72, this being the slowest-burning hexagonal powder on hand.

The projectiles were of two kinds, one being a brass shell fastened to the head of a long wooden spar. This was intended for naval use, and the rounds fired, although given in the firing record, are not further adverted to. The other projectile intended for use in the Army is illustrated in Plate 1.

The projectile, Plate 1, consists of a brass shell (S), with its base surrounded by a brass ring (R), into which a wooden cylinder (C) is inserted and fastened by screws; this cylinder rests upon a rubber buffer (B), fluted on the exterior and containing longitudinal cylindrical perforations; the buffer is surrounded by a hollow brass tube (T) which fits it closely, and finally a series of discs composed of alternate layers of copper (D) and paper (D′) acts as a wad and is intended to close the bore so that the powder gases may not pass over the projectile. The shell is coated on the interior with paraffine and pitch to insure a smooth surface. By varying the proportion of rubber in the buffer and the diameters of the perforations its stiffness can be regulated.

The trial commenced July 25, 1884, when a shell filled with sand was fired down the beach with a 4-pound charge. The total weight of the projectile with all its parts was 34 pounds 14½ ounces. The object of this shot was to try the working of the buffer. On August 16 a shell said to contain 8 pounds 8½ ounces of dynamite was fired down the beach with a 3-pound charge. It struck about 200 yards from the gun, breaking into fragments and scattering, but not exploding the dynamite. A second shell, said to contain 8 pounds 8½ ounces of dynamite, was then fired with a 3-pound charge. This exploded in the bore and destroyed the gun.

The representatives of the Dynamite Projectile Company had made the projectiles from their own plans and at their own expense. They stated that they were of the opinion that the shells were too thin and that the explosion had resulted from the rupture of the brass case.

In a letter of August 28 Mr. Snyder requested that the Government should rebore a 24-pounder gun to 6 inches caliber, and supply him with some projectiles similar to those previously fired, but with thick walls. The Board considered it possible that the rupture of the gun had been caused by the yielding of the walls of the shell, and to settle any doubt on this subject recommended that Mr. Snyder's request for another gun and new projectiles prepared at the expense of the Government should be granted, which recommendation was approved by the Chief of Ordnance September 16, 1884.

The rubber buffers were made as was prescribed by Mr. Snyder. To compensate for the increased weight of the projectile, the walls of the shell were made 0.52 of an inch thick.

On October 10, two rounds, and on October 16 one round was fired with 3-pound charges, the shell containing sand; these rounds being intended to determine the best form of buffer to be used.

In the fourth round of this series a shell said to contain 7 pounds 8 ounces of dynamite was fired over the water and did not burst on striking. The fifth round, fired with the same charge and a shell said to contain 7 pounds of dynamite, was then fired against a thick iron plate and exploded with great violence, but did no appreciable damage; the sixth shot fired against the same plate passed through an old hole in the target and exploded on striking the wood backing, causing but little injury. At the seventh round a shell said to contain 8 pounds 8 ounces of dynamite was fired at the plate but missed it. The same shell was fired in the eighth and ninth rounds, and in the latter case striking the backing at one side of the target exploded. The distance from the piece to the target in the fifth, sixth, seventh, eighth, and ninth rounds was but 100 yards; but the charge, 3 pounds, was so small as compared with the mass projected, which weighed about 60, that the firing was very inaccurate. It was determined, therefore, that a larger charge would have to be used, and 8 pounds was fixed upon, this being between one-seventh and one-eighth the weight of the projectile, and considerably less than the charges of smooth-bore guns, even when comparatively quick-burning powders were used.

A preliminary round with a shell containing 16 pounds 8 ounces of sand was fired. The resulting pressure was less than 18,000 pounds. The shell was recovered uninjured, showing that it was amply strong to endure the shock of discharge without rupture.

In the thirteenth round the shell was loaded under the supervision of an officer, and was found to contain exactly 6 pounds 12 ounces of dynamite, a smaller quantity than had been heretofore reported in any of the shells fired. The charge was as in the preceding round 8 pounds; the total weight projected from the gun by this charge was 61 pounds 8 ounces. In this round the gun was destroyed.

It will be seen from the above recital that every facility has been afforded to the Dynamite Projectile Company, and moreover every precaution suggested by them was taken. The Board, after firing several rounds with 3 pounds of powder, however, directed that a more suitable charge should be used, as has been already remarked.

In conclusion, the Board would state that it is impracticable to fire shells containing commercial dynamite from a smooth-bore gun when a suitable powder charge is used, under the system proposed by the Dynamite Projectile Company.

Although previous experiments by the Board have indicated that explosive gelatine can be successfully fired from an 8-inch rifle with a charge of 40 pounds of powder, and therefore could be safely employed in this case instead of commercial dynamite, yet the Board does not consider that any trial with it in this system would be of any value, because the projectile employed possesses so little penetrative power. This system, furthermore, is very complicated and expensive, and the Board does not recommend further experiments with it, as simpler and less costly methods promise greater and more valuable results.

T. G. BAYLOR,
Colonel of Ordnance, President of the Board.
GEO. W. McKEE,
Major of Ordnance.
CHARLES SHALER,
Captain of Ordnance.

Record of firing with 24-pounder smooth-bore gun No. 35 (reamed to

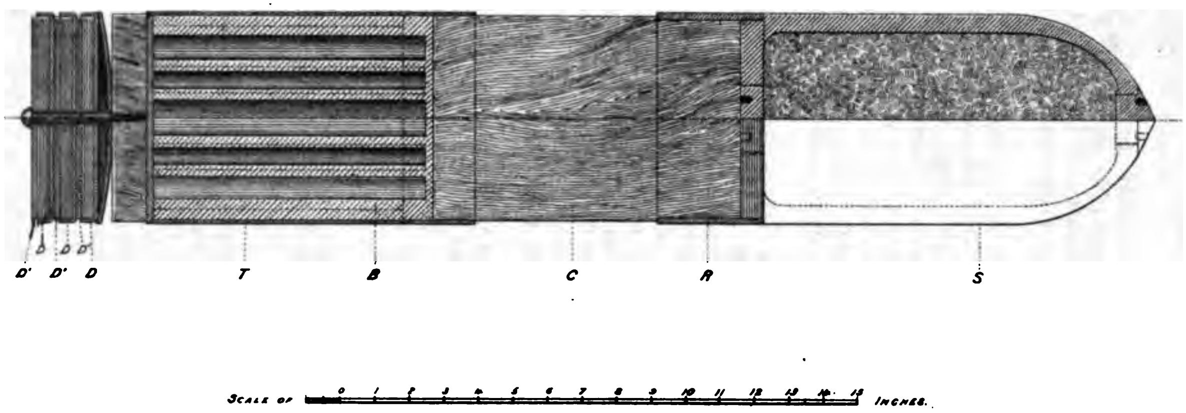
	No. of fire.	Time.		Powder.		Projectile.			Elevation.
		Month.	Day.	Kind.	Weight. Lbs.	Kind.	Weight. Lbs	Weight. Oz.	
		1884.							°
Barometer, 29.931; thermometer, 68.8; humidity, 86.	1	July....	25	Du Pont's hexagonal E. V. M. Density, 1.750; granulation, 72.	4	Brass shell unfilled.	13	6	½
						Rubber buffer	3	4	
						Brass case containing buffer.	8	....	
						Sabot	3	6½	
						Brass shell filled with sand.	21	4	
	2	July....	25		3	Spar, with unfilled shell attached.	47	8	1
						Spar, with filled shell attached (sand).	55	....	
						Rubber buffer	3	4	
						Block..........	2	8	
						Brass case	4	12	
Barometer, 30.223; thermometer, 72.2; humidity, 75.	3	August.	16		2	Brass shell unfilled.	14	....	4
						Brass shell loaded..	22	8½	
						Rubber buffer and brass case.	9	8	
	4	August.	16		3	Brass shell unfilled.	14	...	13
						Brass shell loaded..	22	8½	
						Rubber buffer and brass case.	9	8	

6-inch bore), at Sandy Hook, N. J., from July 25 to August 16, 1884.

Wind, strength and direction.			Special remarks about each fire, such as effect on piece, sound of projectile in flight, scattering of fragments, etc., etc.
From front and left 87°. 6 miles an hour.	Fired down beach. Struck 154 yards from gun.	In these two rounds the buffer was of pure rubber.	Compressed rubber buffer, 2″.75. Shell found 400 yards from gun.
From front and left 12°. 6 miles an hour.	Fired over water		Struck water near shore and skipped wildly perhaps 50 yards; projectile floated and was recovered, indented on one side; gun about 13 feet above water level.
13 miles an hour. From rear and right 43°.	Fired down beach		Dynamite filled in compactly by hand and covered by cork screwed down on top of it. The projectile was coated with ¼-inch mixture of paraffine and asphalt. Buffer 80 per cent. pure rubber. Struck beach 200-250 yards distant, and head broke to pieces and scattered fragments of dynamite over space of 50-75 yards.
From rear and left 48°.	Fired over water		Shell loaded as before. Burst in gun; fragments of every size thrown in every direction over an area the diameter of which perhaps was 200 yards. Chase intact from trunnions thrown 11¼ yards to front and breech 25 yards to rear.

PLATE I.

SNYDER DYNAMITE PROJECTILE



Ordnance Board U.S.A.
Governors Island November 7th 1884.

Appendix 9—1885.

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APPENDIX 10.

TEST OF 15-INCH GUN-CARRIAGE ALTERED AT WATERTOWN ARSENAL, BY THE ORDNANCE BOARD.

An indorsement by the Chief of Ordnance dated June 11, 1884, relating to a 15-inch carriage with a hydraulic cylinder, model of 1884, completed at Watertown Arsenal, directed the Board to make such tests of the carriage as might be deemed necessary and to report the results to the Ordnance Office.

The carriage is in general the same as the one described and illustrated in the Report of the Chief of Ordnance for 1883, page 384 *et seq.*, with the modifications recommended in that report, except that the retraction gear was left unchanged. Furthermore, the rack for retaining the carriage after recoil was attached to the top carriage instead of to the chassis, this change being necessitated when the chassis rails were placed directly under the cheeks of the carriage. Thus arranged the space left outside the shoe-plate was not wide enough to furnish a support for the rack.

The trial commenced October 1, 1884, and consisted in firing sixty rounds with one hundred and thirty pounds of E. V. M. powder under angles of from 2° to 23°, the latter being the highest elevation obtainable. The accompanying firing record gives a detailed account of the trial.

The carriage as a whole worked satisfactorily, but in the course of the firing certain defects were found to require alteration.

The cylinder transoms were made of steel. Three sets broke, a fourth set was cracked. These should hereafter be made of wrought iron.

The piston-head as furnished was too small and did not restrain the recoil sufficiently. It should have the same diameter as in the original carriage.

The liquid escaped at the joint of the rear cylinder-head. A groove should be turned in this joint, one-half in the face of the cylinder, one-half in the face of the head, and steam packing should be placed in this groove before bolting the head to the cylinder. It is thought that this will prevent leakage. The leakage through the stuffing-box for the piston is unimportant in quantity.

The screws in the props under the center of the chassis were upset and their ends made a deep impression on the upper face of the traverse circle. They will therefore have to be rejected and if possible an adjustable plate should be substituted.

The retraction gear recommended on page 387, Report of Chief of Ordnance for 1883, should be applied to carriages hereafter constructed.

It will be observed from the firing record that guide-plate bolts were broken twice. An examination of these bolts appeared to indicate that the iron was of an inferior quality or had been injured in the forging. All bolts should be of the very best material obtainable. It has been found by some years' experience at Sandy Hook, that Burden's best iron is very satisfactory for bolts.

In other respects the carriage and chassis gave satisfactory results.

T. G. BAYLOR,
Colonel of Ordnance, President of the Board.
GEORGE W. McKEE,
Major of Ordnance.
CHARLES SHALER,
Captain of Ordnance.

APPENDIX 10.

TEST OF 15-INCH GUN-CARRIAGE ALTERED AT WATERTOWN ARSENAL, BY THE ORDNANCE BOARD.

An indorsement by the Chief of Ordnance dated June 11, 1884, relating to a 15-inch carriage with a hydraulic cylinder, model of 1884, completed at Watertown Arsenal, directed the Board to make such tests of the carriage as might be deemed necessary and to report the results to the Ordnance Office.

The carriage is in general the same as the one described and illustrated in the Report of the Chief of Ordnance for 1883, page 384 *et seq.*, with the modifications recommended in that report, except that the retraction gear was left unchanged. Furthermore, the rack for retaining the carriage after recoil was attached to the top carriage instead of to the chassis, this change being necessitated when the chassis rails were placed directly under the cheeks of the carriage. Thus arranged the space left outside the shoe-plate was not wide enough to furnish a support for the rack.

The trial commenced October 1, 1884, and consisted in firing sixty rounds with one hundred and thirty pounds of E. V. M. powder under angles of from 2° to 23°, the latter being the highest elevation obtainable. The accompanying firing record gives a detailed account of the trial.

The carriage as a whole worked satisfactorily, but in the course of the firing certain defects were found to require alteration.

The cylinder transoms were made of steel. Three sets broke, a fourth set was cracked. These should hereafter be made of wrought iron.

The piston-head as furnished was too small and did not restrain the recoil sufficiently. It should have the same diameter as in the original carriage.

The liquid escaped at the joint of the rear cylinder-head. A groove should be turned in this joint, one-half in the face of the cylinder, one-half in the face of the head, and steam packing should be placed in this groove before bolting the head to the cylinder. It is thought that this will prevent leakage. The leakage through the stuffing-box for the piston is unimportant in quantity.

The screws in the props under the center of the chassis were upset and their ends made a deep impression on the upper face of the traverse circle. They will therefore have to be rejected and if possible an adjustable plate should be substituted.

The retraction gear recommended on page 387, Report of Chief of Ordnance for 1883, should be applied to carriages hereafter constructed.

It will be observed from the firing record that guide-plate bolts were broken twice. An examination of these bolts appeared to indicate that the iron was of an inferior quality or had been injured in the forging. All bolts should be of the very best material obtainable. It has been found by some years' experience at Sandy Hook, that Burden's best iron is very satisfactory for bolts.

In other respects the carriage and chassis gave satisfactory results.

T. G. BAYLOR,
Colonel of Ordnance, President of the Board.
GEORGE W. McKEE,
Major of Ordnance.
CHARLES SHALER,
Captain of Ordnance.

Record of firing with 15-inch Rodman smooth-bore gun No. 114,

	Number of fire.	Time.	Powder. Kind.	Powder. Weight.	Projectile. Kind.	Projectile. Weight.	Elevation in degrees.	Pressure per square inch of bore (Crusher).	Instrumental velocity 129.5 feet from muzzle.	Recoil.
		1884.		*Lbs.*		*Lbs.*	°	*Pounds.*	*Feet.*	*Feet.*
P. M.—Barometer, 30.147; thermometer, 80.3; humidity, 60.	174	Oct. 1	Du Pont's E. V. M. hexagonal. Density, 1.750; granulation, 72.	130	Round iron solid shot.	456	2	25,000	1,660	5.75
A. M.—Barometer, 30.373; thermometer, 58; humidity, 72.	175	Oct. 3		130		457	2	24,700	1,663 129' 3"	......
P. M.—Barometer, 30.256; thermometer, 53.7; humidity, 44.	176	Oct. 14		130	Round iron solid shot (new).	455	2	23,900	1,657	5.25
	177	Oct. 14		130		455	3	....	....	5.37
	178	Oct. 14		130		455	2	....	....	5.46
A. M.—Barometer, 30.401; thermometer, 43.8; humidity, 47.	179	Oct. 15		130		455	5	....	....	5.00
	180	Oct. 15		130		455	5	....	....	5.04
	181	Oct. 15		130		455	5	....	....	5.04
	182	Oct. 15		130		455	5	....	....	5.04
	183	Oct. 15		130		455	5	....	....	5.04
P. M.—Barometer, 30.321; thermometer, 51.7; humidity, 40.	184	Oct. 15		130		455	10	....	....	5.00
	185	Oct. 15		130		455	10	....	....	5.00
	186	Oct. 15		130		455	10	....	....	5.00
	187	Oct. 15		130		456	10	....	....	5.04
	188	Oct. 15		130		456	10	....	....	5.04
P. M.—Barometer, 30.236; thermometer, 74.5; humidity, 60.	189	Oct. 21		130		456	15	....	....	5.16
	190	Oct. 21		130		456	15	....	....	5.08
	191	Oct. 21		130		456	15	....	....	5.08
	192	Oct. 21		130		456	15	....	....	5.12
	193	Oct. 21		130		456	15	....	....	5.12
P. M.—Barometer, 30.027; thermometer, 57.3; humidity, 64.	194	Nov. 11		130		455	15	....	....	5.08
	195	Nov. 11		130		455	15	....	....	5.16
	196	Nov. 11		130		455	15	....	....	5.16
	197	Nov. 11		130		455	15	....	....	5.16
	198	Nov. 11		130		455	15	....	....	5.16
	199	Nov. 11		130		455	15	....	....	5.25

at Sandy Hook, N. J., from October 1, 1884, *to January* 7, 1885.

Wind, strength, and direction.	Range.	Deflection.	Time of flight.	Special remarks about each fire, such as effect on piece, sound of projectile in flight, scattering of fragments, etc., etc. (Mounted on 15-inch carriage with hydraulic buffer, model 1884.)	
	Yds.	*Yards.*	*Secs.*		
From rear and right 48°; 4 miles an hour.	1831	24 R.	......	Fired to sea to obtain range and try carriage.	25 gallons oil in cylinder. The carriage recoiled against rear buffer, and jumping forward tore off 4 teeth of the ratchet for catching the gun after recoil. The pintle and pintle plate were both bent and two bolts securing piston-rod strap to transom were sheared off in passing over middle chassis transom. These bolts were replaced before round 175. Differential pulley caught during recoil and block broken.
From front and left 48°; 18 miles an hour.	1614	25 R.	3¾	Fired to sea to obtain range and try carriage.	30 gallons oil in cylinder. Carriage recoiled as before, breaking off 7 more teeth of ratchet.
From rear and left 23°; 29 miles an hour.	Lost.	....	4$\frac{1}{16}$	Fired to sea to obtain ranges and try carriage. 27 gallons of oil in cylinder.	Oil leaked out around rear head of cylinder and packing blown out.
	1812	25½ R.	4¼		Cylinder-head bolts tightened.
	1811	43 L.	4		Rear head of cylinder repacked with sheet copper.
From rear and left 23°; 20 miles an hour.	3022	55 R.	8		
	2903	129 R.	8¼		Before firing round 176—New piston head was fitted on as the old one proved to be ⅛ inch smaller in diameter than the inside of cylinder; the pintle and pintle plate were also straightened; the toe of the ratchet pawl was reset and new ratchet attached.
	2904	108 R.	8¼		
	2966	8 R.	8¼		
	2966	8 R.	8		
From rear and left 23°; 12 miles an hour.	Lost.	....	14		
	4691	59½ L.	13¾		
	4440	24 R.	13¾		
	4565	24 R.	14⅛		
	Lost.	....	14		
From front and right 23°; 8 miles an hour.	6051	13 L.	19¼		
	5723	6 L.	19¾		
	5560	20 R.	19½		Lower step for crane broke.
	5682	44 R.	20		
	5616	73 R.	19⅜		Gun washed out, examined, star gauged, and impressions taken at vent. Firing delayed to rebush vent.
From rear and right 48°; 4 miles an hour.	5488	117 R.	19¼		
	5615	184 R.	19		
	5313	161 R.	19¼		
	5484	59 R.	19¼		Oil commenced leaking slightly from rear head of cylinder.
	5289	46 R.	18¼		
	5483	113 R.	19		

Record of firing with 15-inch Rodman smooth-bore gun No. 114,

	Number of fire.	Time.	Powder.		Projectile.		Elevation.	Pressure per square inch of bore (Crusher).	Instrumental velocity 129.2 feet from muzzle.	Recoil.
			Kind.	Weight.	Kind.	Weight.				
		1884.		*Lbs.*		*Lbs.*	°	*Pounds.*	*Fee .*	*Feet.*
P. M.—Barometer, 30.027; thermometer, 57.3; humidity, 64.	200	Nov. 11	exagonal. Density, 1.750; granulation, 72.	130	d iron solid shot (new).	455	15	....	....	5.25
	201	Nov. 11		130		455	15	....	....	5.25
	202	Nov. 11		130		455	15	....	....	5.25
	203	Nov. 11		130		455	15	....	....	5.25
	204	Nov. 11		130		455	20	....	....	5.25
	205	Nov. 11		130		455	20	....	....	5.32
	206	Nov. 11		130		455	20	....	....	5.25
	207	Nov. 11		130		455	20	....	....	5.25
	208	Nov. 11		130		455	20	....	....	5.25
A. M.—Barometer, 30.116; thermometer, 49.9; humidity, 65.	209	Nov. 12		130		457	20	....	....	5.25
	210	Nov. 12		130		457	20	....	....	5.25
	211	Nov. 12		130		457	20	....	....	5.33
	212	Nov. 12		130		457	20	....	....	5.33
	213	Nov. 12		130		457	20	....	....	5.33
		1885.								
A. M.—Barometer, 29.505; thermometer, 47.1; humidity, 67.	214	Jan. 7		130		454	20	....	....	5.00
	215	Jan. 7		130		454	20	....	....	5.00
	216	Jan. 7		130		454	20	....	....	5.00
	217	Jan. 7		130		454	20	....	....	5.08
	218	Jan. 7		130		454	20	....	....	5.00

at Sandy Hook, N. J., from October 1, 1884, *to January* 7, 1885—Continued.

Wind, strength and direction.	Range.	Deflection.	Time of flight.	Special remarks about each fire, such as effect on piece, sound of projectile in flight, scattering of fragments, etc., etc. (Mounted on 15-inch carriage with hydraulic buffer, model 1884.)
	Yds.	*Yards.*	*Secs.*	
From rear and right 48°; 4 miles an hour.	5502	181 R.	19¼	Fired to sea to obtain ranges and try carriage. 27 gallons of oil in cylinder.
	5348	69 R.	18⅜	
	Lost.	....	19	
	Lost.	....	19⅛	
	6526	183 R.	Lost.	
	6606	46 L.	24¼	Rear bolt of left guide-plate broken.
	6353	41 R.	23⅛	
	Lost.	....	24⅛	
	Lost.	....	23⅛	Rear head of cylinder tightened.
From rear, 6 miles an hour.	6191	139 R.	23¼	
	Lost.	....	23¾	
	6152	219 R.	24	
	Lost.	....	23¾	
	6216	178 R.	23⅛	Lower front and middle transom plates for cylinder fractured.
From rear and right 48°; 36 miles an hour.	6405	39 L.	Lost.	All the cylinder straps being found broken or cracked, new ones were obtained from Watertown Arsenal and fitted to carriage before round 214, and prop screws (being upset) were removed and the props wedged up by plates. Round 214—Upper half middle cylinder transom cracked on right side, and after 5 rounds had increased so as to extend half way across.
	6593	64 R.	Lost.	
	6631	15 R.	24	
	6501	14 R.	23⅛	
	6587	13 R.	23¾	A bolt of left guide plate and elevating prop broke.
	7168	51 R.	26	
	7155	46 L.	26¼	
	7323	22 R.	26¾	Right guide plate broken off; repaired.
	7165	171 R.	26⅜	
From rear and right 48°; 36 miles an hour.	Lost.	Lost.	Lost.	
	7195	81 R.	26⅛	
	7090	68 R.	26⅛	
	7018	101 R.	26⅜	
	6961	16 R.	26⅛	
	7026	136 R.	25⅞	
	6962	103 L.	25¾	
	7074	142 R.	26¾	
	6931	93 L.	26⅛	
	7022	19 R.	26	
	7046	183 R.	26⅝	

APPENDIX 11.

THAYER'S DIRIGIBLE BALLOON. BY THE ORDNANCE BOARD.

(Five plates.)

A letter from the Chief of Ordnance, dated January 23, 1885, stated that the Secretary of War had invited Mr. Russell Thayer, of Philadelphia, to appear before the Ordnance Board to explain his invention for the propulsion of balloons at a high rate of speed, and the same letter directed the Board to give to Mr. Thayer an interview, examine his plans, and make a report thereon to the Ordnance Office.

Mr. Thayer appeared before the Board and read a paper, herewith inclosed, describing his inventions, and also presented his patents, with specifications covering the same. The Board does not agree with Mr. Thayer as to the reasons given for the movement of his balloon, but after consideration of his plans deems them feasible and worthy of trial, in view of the great value and importance of such a machine for war purposes if it can be made to work practically. The trial in order to be complete and satisfactory should be made with a machine of a sufficient size to prove its efficiency under all ordinary circumstances. The Board therefore recommends that a machine of about 7 tons ascending force be constructed and trials be made with it. The cost of this machine complete is understood to be about $5,000.

T. G. BAYLOR,
Colonel of Ordnance, President of the Board.
GEO. W. McKEE,
Major of Ordnance.

The extreme thinness and elasticity of the medium in which the body floats has baffled the ingenuity of the engineer and inventor in the application of a force for the propulsion of the aerial ship.

All methods of propulsion heretofore known have been tried and been found wanting. The idea, in every instance, has been to apply a surface of some resisting matter endowed with force against the air, the object in view being to obtain thereby a reactive force that would propel the air-ship through the atmosphere. Ignorant persons have suggested wheels, oars, and similar contrivances, while accomplished engineers, as De Lome and Gifford, have tried to adopt the propeller to the solution of the problem. All attempts heretofore made have practically been failures, although to Mr. Henri Gifford, the celebrated French engineer, the credit of first attempting to apply steam for the propulsion of a dirigible balloon can be given.

Another most important point in the final solution of the problem must be here referred to, viz, that it is only within the last few years that it has become possible to construct machinery of great power and extreme lightness combined with strength.

Mr. William Pole, F. R. S., M. Inst. C. E., in the year 1882 read a paper before the Institution of Civil Engineers of Great Britain, and discussed in a practical manner the problem of aerial navigation. The conclusions reached by him were as follows, viz:

(1) The problem of aerial navigation by balloons is one as perfectly amenable to mechanical investigation as that of aquatic navigation by floating vessels, and its successful solution involves nothing unreasonable or inconsistent with the teachings of mechanical science.

(2) It has been fully established by experiment that it is possible to design and construct a balloon which shall possess the conditions necessary for aerial navigation, viz, which shall have a form of small resistance, should be stable and easy to manage, and, if driven through the air, shall be capable of steering by a proper obedience of the rudder.

(3) Sufficient data exist to enable an approximate estimate to be made of the power necessary to propel such a balloon with any given velocity through the air.

(4) The recent reduction in the weight of steam-motors has rendered it possible to carry with the balloon an amount of power sufficient to produce moderately high speed, say 20 or 30 miles an hour through the air, and by taking advantage of other recent improvements it would also be possible to carry a moderate supply of fuel and water for the working.

(5) The practical difficulties in the way are only such as naturally arise in the extension of former successful trials, and such as may reasonably be expected to give way before skill and experience.

Mr. Pole's entire investigation of the subject, and the conclusions deducted, are based on the screw propeller as furnishing a practical means for the propulsion of an aerial ship.

A glance at the tabular results reached by him shows that as a means of applying the force generated, the steam-propeller is a most unsuitable and impracticable machine. Fancy a propeller 60 feet in diameter (the size required for a large aerial ship) and conveying a thrust of 3,000 pounds. The difficulties of constructing such an arrangement that would be of sufficient lightness and strength, and at the same time manageable, are insurmountable and preclude its use for the purpose in question.

The propeller is a most suitable contrivance for the propulsion of ships in heavy, incompressible fluid like water, especially where weight is no consideration, but is totally unsuited for the propulsion of bodies in an extremely attenuated and elastic medium as the air.

The conditions which obtain in regard to a body floating in the air are similar to those which exist in the case of a ship floating in the water. In both instances the structure is supported in the medium in which it floats, against the action of the force of gravity, by the weight of the fluid displaced, this weight acting vertically upwards in opposition to the force of gravity acting vertically downwards through the center of gravity. The force acting vertically upwards and sustaining the body in the fluid is called the "buoyant effort," and its intensity is equal to the weight of the fluid displaced. Its line of direction passes through the center of gravity of the displaced fluid, and this point is called the center of buoyancy. The following conclusions result from a thorough investigation of this branch of the subject, viz:

(1) The pressures upon the surface of a body immersed in a fluid have a single resultant called the "buoyant effort," and this resultant is directed vertically upwards.

(2) The buoyant effort is equal in intensity to the weight of the fluid displaced.

(3) The line of direction of the buoyant effort passes through the center of gravity of the displaced fluid.

(4) The horizontal pressures destroy one another.

In regard to the equilibrium of the floating body, I may state that it will be stable as long as the center of gravity of the body is below that of the displaced fluid. In the aerial ship that I have designed this condition will be always fulfilled, and consequently the structure cannot capsize.

Practical experiments and mathematical deductions prove that the best shape for the buoyant portion of the structure under discussion is that of a circular spindle in which $L = 3\frac{1}{2}\ d$, L representing the longer or horizontal axis and d the diameter amidships. This shape will give the least resistance to motion through the air, will comply with the conditions of stable equilibrium, and will give good steering qualities.

The ascending force of the gas, hydrogen being used, will be represented by the expression $A\ d^2\ l$, in which d and l represent quantities as above and A being a coefficient depending upon the shape of the vessel and on the specific gravity of the gas compared with that of the surrounding air. Supposing pure hydrogen gas to be used, the levity of 1 cubic foot = 0.0751 of a pound, and with the shape above given the ascending force determined by actual experiments may be represented by the expression $0.03\ d^2\ l$.

The resistance of the ship to motion through the air has been accurately determined by three methods, viz, by the midship-area calculation, skin-friction calculation, and cubic-displacement calculation; and based upon the conditions that $l = 3\frac{1}{2}\ d$, the following resistances have been obtained, viz:

By the midship area = $0.000172\ d^2\ v^2$
By the skin friction = $0.000173\ d^2\ v^2$
By the cubic displacement = $0.000211\ d^2\ v^2$

in which d represents as above and v = velocity in feet per second of time. Taking a mean of the two last expressions (the largest), the formula giving the resistance to the motion forward through the atmosphere becomes $X = 0.000193\ d^2\ v^2$

THE THEORY OF ACTION OF THE MOTOR.

To return now to the subject of the propelling force, I will observe that the idea of beating the air (a medium of extreme rarity) with a propeller in order to generate a reactive force forward is impracticable, not only on account of the practical difficulties in the way as before suggested, but also and principally by reason of the unsubstantial character of the medium upon which the force is made to act and the great waste of power resulting from any such method. After careful investigation of the subject I was forced to adopt the conclusion that the propelling force must reside in the motor itself, and must be applied within itself in such a manner as to promote motion forward.

The action of the motor is entirely independent of extraneous conditions, and will produce high rates of motion without applying force against any extraneous resisting medium.

In all ordinary applications of force to produce motion we see the force generated applied against some resisting substance. The steamboat is propelled by the reaction resulting from the action of the blade of the paddles or screw upon the dense medium of the water. The locomotive engine moves forward by reason of the peripheries of the drivers rolling along the rail, but the tires must grip the rail before motion results.

of, say, 100 pounds to each square inch; suppose the area of each cylinder-head = 10 square inches. Under these circumstances the total pressure on the head *a b* will = 10 by 100 = 1,000 pounds. On the head *c d* there will be only 9 square inches upon which the force within the cylinder can act; consequently the pressure on this end of the cylinder = 9 by 100 = 900 pounds. All the other forces within the cylinder are in a condition of equilibrium, for the reason that they are all acting, respectively, in directly opposite directions and are equal. Therefore, the resultant of forces = 1,000 pounds — 900 pounds = 100 pounds, acting in the direction B A, and this produces motion in that direction due to said resultant.

We have here generated a powerful force, and applied it in such a way as to produce motion with the simplest possible mechanism and entirely independent of extraneous conditions.

Motion can be produced by this principle in a perfect vacuum, remote from the reach and influence of all terrestrial objects; indeed, it is evident that in a vacuum the motion of a body impelled by the action of a force resident within the motor itself, by the principle above described, would be at a far higher rate of speed than would be the case in the air, for the reason that the medium in which the body is traveling, viz, the air, offers considerable resistance to motion due to friction.

The motor I have devised enables me to accumulate, produce, and apply an extremely powerful force. It consists essentially of a high-speed air-compressor coupled directly to a specially designed gas-engine, and a reservoir, called an accumulator, into which the compressed air is forced. The rear end of this reservoir is so arranged that at given intervals of time, a few seconds apart, the confined energy is suddenly released, thus producing a powerful motive thrust forward, due to the fact of the unstable condition of equilibrium of forces at the instant of discharge. The amount of power thus rendered available is dependent upon the size of the reservoir and its discharge. It is also, of course, a function of the time of charging and the number of strokes of the engine made therein. In the motor here described for aerial navigation the impact of the escaping air or vapor, under high pressure, against the particles of the surrounding air in which the body is floating, tends to increase the resultant action forward; but the principal portion of the motion forward is caused by the continuous condition of unstable equilibrium of forces producing a resultant action, as above described, in a given direction. The reaction resulting from the impact of the escaping gas upon the particles of the surrounding medium is small in comparison with the resultant of the forces in unstable equilibrium, but slight as it is it acts in the proper direction.

I regard the aperture at the rear of the motor mainly as a means for the escape of the wasted energy; its size is so proportioned as to produce the maximum condition of unstable equilibrium of forces.

I will now proceed to a description of the dirigible balloon, the plans of which accompany this paper. As will be seen from the drawings, it consists essentially of two portions. The buoyant part, which corresponds to the hull of a water ship, is made of superposed tissues of strong silk and rubber, and the shape is that of a circular spindle, in which the long horizontal axis = $3\frac{3}{8}$ times the length of the diameter amidships; this structure is filled with hydrogen gas.

The deck of the ship, upon which the machinery is located, and where men with dynamite percussion cartridges or a Gatling gun can be placed, is below the buoyant part of the structure, and is firmly supported therefrom and braced thereto, as shown.

Opposite the center of the ship there is a lower deck, completely inclosed and separated from the rest of the structure, in which the power is located. From the cylinder of the motor a pipe leads all or part of the wasted energy utilized in the production of motion to the stern of the ship, and is there terminated by a nozzle fitted on a ball and socket joint. This arrangement permits the nozzle to be moved in any direction at pleasure, and by a movement of the nozzle from the wheel the ship may be steered in any direction that may be desired, thus avoiding the necessity for any rudder.

While the machinery is in motion and the force is being generated the ship is under perfect control and can be directed in any course that may be required. It is not necessary that the entire amount of wasted energy should be discharged at the stern of the ship and used for steering, and it is preferable not to do this, but to discharge the air or vapor near the motor and thus avoid the friction in the tube; a portion sufficient only to give good steering power should be taken to the nozzle at the stern.

In the interior of the buoyant portion of the ship is placed a large silk sack, connected with the air-compressor on the deck, and a pipe leads from the exterior envelope to the tube leading to the nozzle at the stern. Both of these pipes are provided with cocks, which can be opened or shut at pleasure.

There are four cylinders filled with compressed hydrogen on the deck of the ship, which are connected with the interior of the exterior envelope and are provided with cocks.

These appliances enable the aerial ship to travel at any elevation above the earth, and to ascend or descend in the atmosphere without the use of ballast. By simply withdrawing hydrogen from the interior of the exterior envelope and forcing air into the interior of the interior sack the buoyancy of the structure is diminished while its exterior form is not changed, and the ship will descend; the reverse of this operation will restore the original buoyancy and cause the ship to ascend. The importance of this matter will be appreciated when it is remembered that it is not proposed to travel habitually at high altitudes, but at elevations of a few hundred feet only, sufficient to clear terrestrial objects.

The following examples show the carrying capacities of aerial ships of various sizes, with the speed per hour and total resistance met with at the respective rates of motion; these elements are calculated from the formulas heretofore given in this paper:

In all cases d=diameter amidships, $l = 3\frac{2}{3}d$ = length.

$d = 30'$ $l = 110'$

Total ascending force, 2,970 pounds.

Resistance, 10 miles per hour, 38.04+ pounds; 20 miles per hour, 149.11+ pounds.

$d = 40'$ $l = 147'$

Total ascending force, 7,040 pounds = 3½ tons.

Resistance, 10 miles per hour, 67.62 pounds; 20 miles per hour, 265.10 pounds.

$d = 50'$ $l = 183'$

Total ascending force, =13,725 pounds = say, 7 tons.

Resistance, 10 miles per hour, =105.66 pounds; =20 miles per hour, 414.22 pounds.

$d = 75'$ $l = 275'$

Total ascending force, 46,400 pounds = 23 tons.

Resistance, 20 miles per hour, 931.92 pounds; 40 miles per hour, 3,727.69 pounds.

$d = 100'$ $l = 367'$

Total ascending force, =110,000 pounds = 55 tons.

Resistance, 10 miles per hour, =422.67 pounds; 20 miles per hour, =1.656.90 pounds; 40 miles per hour, =6,627.62 pounds.

Note these resistances at the speed specified and observe how very small they are in comparison to the size of the aerial ship and its carrying capacity. It is only necessary for the motor to develop a force equal to the resistance, in any instance, to pro-viz, by sending a few men in a balloon of this description, in the day or night time, over a hostile town or fleet, and dropping down on to the enemy dynamite percussion cartridges. The effects would be very disastrous to the enemy, and there would be no way of avoiding the results.

A dynamite cartridge dropped on the deck of any form of ship would most probably sink her, or a Gatling gun can be used.

Of course there are other uses to which the structure that I have described could be devoted for military purposes. I simply have mentioned a few that have suggested themselves.

I feel satisfied from the experiments that I have made on a small scale that the apparatus is practical, and for a comparatively speaking small sum a war balloon can be built which would be exceedingly useful to the Government.

BALLOON OR AERIAL SHIP.

RUSSELL THAYER, of Philadelphia, Pa.

[Specification forming part of letters patent No. 309008, dated December 9, 1884. Application filed November 23, 1883. (No model.)]

To all whom it may concern:

Be it known that I, Russell Thayer, of the city of Philadelphia, county of Philadelphia, and State of Pennsylvania, have invented an improvement in balloons or aerial ships, of which the following is a specification.

My invention has reference to balloons or aerial ships; and it consists in providing the same with devices to produce and maintain a supply of gas or vapor in a receiver and force the same from a discharging-nozzle at the rear of the balloon or air-ship under considerable pressure, whereby an unstable equilibrium of forces generated by the compressed gas or vapor in the receptacle is produced, and in details of construction, all of which are fully set forth in the following specification and shown in the accompanying drawings, which form part thereof.

The object of this invention is to provide a balloon or aerial ship with simple and effective means for navigating the same, irrespective of the air-currents in which it floats, whereby a great velocity is attained and the vessel made manageable; further, to dispense with the usual large wind-wheels or air-propellers, and all such devices which are bulky, unmanageable, and require a great power to work them.

In order to move in the air, I develop forces in unstable equilibrium acting upon the structure itself, and producing a resultant power which will cause the ship to move in the direction in which said resultant is made to act.

In the motor here described for aerial navigation the impact of the escaping air under high pressure against the particles of the surrounding air in which the body is floating tends to increase the resultant action forward; but the principal portion of the motion forward is caused by the continuous condition of unstable equilibrium of forces, producing a resultant action, as above described, in a given direction. The reaction resulting from the impact of the escaping gas upon the particles of the surrounding medium is small in comparison with the resultant of the forces in unstable equilibrium, but slight as it is it acts in the proper direction. I regard the aperture at the rear of the motor mainly as a means for the escape of the wasted energy. Its size is so proportioned as to produce the maximum conditions of unstable equilibrium of forces.

In the drawings, Figure 1 is a side elevation of my improved navigable aerial ship. Fig. 2 is a plan view of the upper or machine deck. Fig. 3 is a plan view of the lower or boiler deck, and Fig. 4 is an elevation (part in section) showing the mechanism for making the aerial ship rise or descend in the air.

A is the balloon proper or gas-receptacle, and is preferably made cigar-shaped and filled with hydrogen gas.

B is the net-work which surrounds the balloon A, and carries by ropes C the machine deck D, to the under part of which is supported the boiler-deck E.

F is the rudder, which may be formed like a mainsail of a yacht, and is moved by tiller-ropes G, which pass around blocks *g g*, and are secured to the tiller-wheel H in the forward part of the deck D.

I are the boilers or gas-holders and J is the smoke-pipe, which may extend downward, as shown, and deliver the smoke from the gas below the deck E, so as to allow the upper deck to remain clear and prevent injury to the silk or other material constituting the balloon proper.

K is a steam or gas air-compressor, in which air is compressed and delivered by a pipe, L, to a reservoir, M, under high pressure. From the reservoir M it is allowed to rush through the discharging nozzle N with any desired velocity, which is regulated by means of the valve *n*. If desired, the end N′ of the nozzle N may be hinged or pivoted on a universal joint, as at N^2, so that by setting said pivoted section at an angle the vessel may be quickly turned or made to travel in a curved line and raised or lowered at will. This may be used in conjunction with the rudder F, and will be advantageous, particularly when traveling with the wind.

In place of using the intermediate reservoir M, the air may be forced direct from the compressor into the discharging nozzle or pipe, which extends out of the rear of the ship and below the rudder; but by using a reservoir the pulsations of the discharged air due to the intermittent action of the compressor will not be felt by the ship, and as the air in the receiver exerts an equal and opposite pressure on all sides, except in the rear, where the discharging-nozzle is placed, and which, if it were not for said nozzle, would have been in stable equilibrium, is now unstable, the vessel is propelled with a force equal to the difference in pressure on the front and back of the said reservoir and the reactionary effect of the compressed air upon the atmosphere in its exit.

The exhaust-steam from the compressor K may be condensed in a condenser, O, and pumped back into the boilers I. The condenser may be kept cool by circulation of a refrigerating-liquid cooled in a refrigerator, P, and circulated by a pump, Q; or the steam may be condensed by a chemical refrigerator alone.

It is advisable to use the condensed steam, as the consumption of water would vary the burden of the vessel, and cause it to rise when not desired, and to prevent this it would be necessary to allow an equivalent of the hydrogen gas to escape. By using a gas-engine instead of a steam-engine we entirely avoid this difficulty, and we avoid entirely all danger from fire and the weight of water and coal or other fuel for the engine. The gas-fuel for the gas-engine is compressed, before starting, into a receiver.

To regulate the vertical travel of the balloon or ship in the air without varying the tension in the receptacle A, I provide the said receptacle with a smaller flexible receptacle, A′, located within the larger.

R is a strong reservoir into which hydrogen gas is forced under very high pressure.

S is a compressor or force-pump, which may be operated by steam or hand power.

t is a pipe connecting with the receptacle or balloon A, and has two branches, t' t^2, provided with valves, one of which connects with the hydrogen tank R and the other with the suction of the compressor S.

W′ is an air-suction pipe for the compressor, and is also provided with a valve.

U is an air-pipe connecting the air receptacle A′ with the discharge of the compressor by a pipe, V, which is provided with a valve, and also with a discharge-pipe, W, provided with a valve, which pipe opens into the atmosphere. The discharge of the compressor is also connected by a valve-pipe, V′, with the hydrogen-tank R.

To ascend, air is allowed to escape by pipe W from vessel or bag A′, and hydrogen is passed into the receptacle A from tank R by pipes t' t until the receptacle A is filled out. To descend, hydrogen is allowed to escape into the atmosphere from balloon or receptacle A, or is drawn through pipes t t^2 and forced into the tank R by compressor S and pipe V′, and air is then sucked in pipe W′ and forced by compressor S through pipes V and U into bag A′ to fill out the receptacle A, as before.

In place of air, any other gas—as bisulphide-of-carbon vapor or carbonic oxide—may be forced through nozzle N.

I do not limit myself to the details of construction, as my invention comprehends the application of air, gas, or vapor kept in unstable equilibrium in a receiver and allowed to escape in the rear of an aerial ship in order to propel the same forward.

Having now described my invention, what I claim as new, and desire to secure by letters patent, is—

(1) The combination, in an aerial ship, of the hydrogen or gas receptacle made oblong or cigar-shaped, decks, ropes connecting said decks with said gas receptacle, boilers I, and air-compressor K, supported upon said decks, a discharging-pipe, N, extending rearward and connecting with said compressor, and the rudder F, arranged above said discharging-pipe and below the gas-receptacle, substantially as and for the purpose specified.

(2) The combination, in an aerial ship, of the hydrogen or gas receptacle, made oblong or cigar-shaped, decks, ropes connecting said decks with said gas-receptacle, boilers I, reservoir M, an air-compessor, K, supported upon said decks, a pipe connecting said reservoir with said compressor, a discharging-pipe, N, extending rearward and connecting with said compressor through said reservoir, and the rudder F, arranged above said discharging-pipe and below the gas-receptacle, substantially as and for the purpose specified.

(3) The combination of gas-receptacle A with the inner receptacle A′, a hydrogen-tank, R, a compressor, S, and connecting-pipes and valves by which the gas may be transferred to or from receptacle A and air to or from receptacle A′, substantially as and for the purpose specified.

(4) An aerial ship formed with an oblong or cigar-shaped gas-receptacle, and

supporting a reservoir into which air is forced under pressure, and an adjustable discharge-nozzle opening from the rear end of said reservoir and projecting rearwardly from the balloon or aerial ship, substantially as and for the purpose specified.

In testimony of which invention I hereunto set my hand.

RUSSELL THAYER.

Witnesses:
NATHL. E. JANNEY.
JOS. J. KNOX.

MOTOR.

RUSSELL THAYER, of Philadelphia, Pa.

[Specification forming part of Letters Patent No. 309,009, dated December 9, 1884. Application filed March 17, 1884. (No model.)]

To all whom it may concern:

Be it known that I, Russell Thayer, of the city and county of Philadelphia, and State of Pennsylvania, have invented an improvement in motors, of which the following is a specification.

My invention has reference to the propulsion of aerial ships, land vehicles, and marine vessels; and it consists in said aerial ships, vehicles, or vessels, provided with means to compress air, and an intermittent storage-reservoir having discharging-valves at one or both ends, said valves being intermittently operated to allow sudden discharges of the air or vapor compressed into said reservoir, whereby the forces of the air compressed in said reservoir when rendered unstable are enabled to react upon one end of said reservoir, to cause the said aerial ship, land vehicle, or marine vessel to be propelled and in details of construction, all of which are fully set forth in the following specification, and shown in the accompanying drawings, which form part thereof. By forcing the air into a reservoir so constructed that when the pressure therein reaches a certain amount a large opening would be automatically provided for the instantaneous discharge or escape of the compressed air or vapor at one end of said reservoir a very great increase in propelling power can be rendered available, for the reason that at the instant previous to the discharge from the reservoir the forces generated therein by the compressed air or gas acting against its extensive internal surface will be in a condition of stable equilibrium, but at the instant the end of the reservoir is opened these forces on that end will be released, while those on the other end are still acting, consequently at that moment the reservoir would take up a motion due to the unsupported action on the closed end, and as the reservoir is a part of the motor and the motor is a part of the entire structure to be propelled, it will move in the direction opposite to that from which the spent energy is released. By varying the area of the discharge and the pressure of the compressed air any desired force may be produced for use in propelling.

In the drawings, Fig. 1 is a side elevation of an aerial ship having my improved motor attached thereto. Fig. 2 is a side elevation (with the reservoir in section) of my improved motor. Fig. 3 is a plan view of same. Fig. 4 is an end view of the reservoir, showing the discharge-ports. Fig. 5 is a plan view of the reservoir discharge-valves. Fig. 6 is an outline of a marine ship having my improved motor applied thereto; and Fig. 7 is a side elevation of a land vehicle having my improved motor applied thereto.

A represents the aerial ship, land vehicle, or marine vessel. B is the deck or floor upon which the motor is applied. C is the boiler; C′, the smoke-stack; D, the air-compressor; E, the intermittent storage-reservoir. The compressor D draws in air by valves *d* and discharges it by pipe F into the side of the reservoir E. This reservoir may be made in any manner desired, having one or both its heads G provided with discharge-valves. These heads G may have ports *g*.

H is a central shaft supported by the heads. Loosely supported upon this shaft H, and against the inner faces of heads G, are the circular valves I, having apertures *i*, to correspond with the openings *g* in the heads. These valves have clutch-hubs J. Upon the shaft H between the heads is a longitudinally-reciprocating sleeve, K, rotated or rocked with the shaft H by means of feathers *k*′. This sleeve is provided with circumferential groove K′ and a clutch, *k*, on each end, which are adapted to mesh with the clutches J on valves I. This sleeve may be moved longitudinally to mesh with either of said valves by an arm, L, secured to a rock-shaft, L′, and adapted to be rocked by a hand-lever, M, which may be set in either of its extreme positions by detent-pawl *m*, catching in notches *n* in segment N.

The shaft H may be intermittently rocked by hand or any suitable automatic mechanism—for instance, as shown—in which an arm O, is secured to the end of the shaft H outside the reservoir, and is drawn in one direction by a spring, O′, and pulled in the other by a bell-crank lever, S, pivoted to a frame, T, and having its free arm provided with a pin, *s*.

R is a ratchet-wheel, which is supported in a bearing, R′, and provided with a pin, *Record of firing with 15-inch Rodman smooth-bore gun No.* 114,

	Number of fire.	Time.	Powder.		Projectile.		Elevation.	Pressure per square inch of bore (Crusher).	Instrumental velocity 129.2 feet from muzzle.	Recoil.
			Kind.	Weight.	Kind.	Weight.				
		1884.		*Lbs.*		*Lbs.*	°	*Pounds.*	*Feet.*	*Feet.*
P. M.—Barometer, 30.027; thermometer, 57.3; humidity, 64.	200	Nov. 11	Du Pont's E. V. M. hexagonal. Density, 1.750; granulation, 72.	130	Round iron solid shot (new).	455	15	....	....	5.25
	201	Nov. 11		130		455	15	....	....	5.25
	202	Nov. 11		130		455	15	....	....	5.25
	203	Nov. 11		130		455	15	....	....	5.25
	204	Nov. 11		130		455	20	....	....	5.25
	205	Nov. 11		130		455	20	....	....	5.32
	206	Nov. 11		130		455	20	....	....	5.25
	207	Nov. 11		130		455	20	....	....	5.25
	208	Nov. 11		130		455	20	....	....	5.25
A. M.—Barometer, 30.116; thermometer, 49.9; humidity, 65.	209	Nov. 12		130		457	20	....	....	5.25
	210	Nov. 12		130		457	20	....	....	5.25
	211	Nov. 12		130		457	20	....	....	5.33
	212	Nov. 12		130		457	20	....	....	5.33
	213	Nov. 12		130		457	20	....	....	5.33
A. M.—Barometer, 29.505; thermometer, 47.1; humidity, 67.	214	1885. Jan. 7		130		454	20	....	....	5.00
	215	Jan. 7		130		454	20	....	....	5.00
	216	Jan. 7		130		454	20	....	....	5.00
	217	Jan. 7		130		454	20	....	....	5.08
	218	Jan. 7		130		454	20	....	....	5.00
	219	Jan. 7		130		454	23	....	....	5.00
	220	Jan. 7		130		454	23	....	....	5.00
	221	Jan. 7		130		454	23	....	....	5.08
	222	Jan. 7		130		458	23	....	....	5.08
P. M.—Barometer, 29.558; thermometer, 42.3; humidity, 69.	223	Jan. 7		130		458	23	....	....	5.00
	224	Jan. 7		130		458	23	....	....	5.00
	225	Jan. 7		130		458	23	....	....	5.08
	226	Jan. 7		130		458	23	....	....	5.08
	227	Jan. 7		130		457	23	....	....	5.08
	228	Jan. 7		130		456	23	....	....	5.08
	229	Jan. 7		130		456	23	....	....	5.08
	230	Jan. 7		130		455	23	....	....	5.08
	231	Jan. 7		130		455	23	....	....	5.16
	232	Jan. 7		130		453	23	....	....	5.08
	233	Jan. 7		130		452	23	....	....	5.08

at Sandy Hook, N. J., from October 1, 1884, *to January* 7, 1885—Continued.

Wind, strength and direction.	Range.	Deflection.	Time of flight.		Special remarks about each fire, such as effect on piece, sound of projectile in flight, scattering of fragments, etc., etc. (Mounted on 15-inch carriage with hydraulic buffer, model 1884.)
	Yds.	*Yards.*	*Secs.*		
From rear and right 45°; 4 miles an hour.	5502	181 R.	19¼	Fired to sea to obtain ranges and try carriage. 27 gallons of oil in cylinder.	
	5348	69 R.	18⅜		
	Lost.	....	19		
	Lost.	....	19⅛		
	6526	183 R.	Lost.		
	6606	46 L.	24¼		Rear bolt of left guide-plate broken.
	6353	41 R.	23⅛		
	Lost.	....	24⅛		
	Lost.	....	23⅛		Rear head of cylinder tightened.
From rear, 6 miles an hour.	6191	139 R.	23¼		
	Lost.	....	23¾		
	6152	219 R.	24		
	Lost.	....	23¾		
	6216	178 R.	23⅛		Lower front and middle transom plates for cylinder fractured.
From rear and right 45°; 20 miles an hour.	6405	39 L.	Lost.		All the cylinder straps being found broken or cracked, new ones were obtained from Watertown Arsenal and fitted to carriage before round 214, and prop screws (being upset) were removed and the props wedged up by plates. Round 214—Upper half middle cylinder transom cracked on right side, and after 5 rounds had increased so as to extend half way across.
	6593	64 R.	Lost.		
	6631	15 R.	24		
	6501	14 R.	23⅛		
	6537	18 R.	23¾		A bolt of left guide plate and elevating prop broke.
	7168	51 R.	26		
	7155	46 L.	26¼		
	7323	22 R.	26¾		Right guide plate broken off; repaired.
	7165	171 R.	26⅝		
From rear and right 45°; 36 miles an hour.	Lost.	Lost.	Lost.		
	7195	81 R.	26⅛		
	7090	68 R.	26¼		
	7018	101 R.	26⅜		
	6961	16 R.	26⅛		
	7026	136 R.	25⅞		
	6962	103 L.	25¾		
	7074	142 R.	26¾		
	6931	93 L.	26⅛		
	7022	19 R.	26		
	7046	133 R.	26⅝		

APPENDIX 11.

THAYER'S DIRIGIBLE BALLOON. BY THE ORDNANCE BOARD.

(Five plates.)

A letter from the Chief of Ordnance, dated January 23, 1885, stated that the Secretary of War had invited Mr. Russell Thayer, of Philadelphia, to appear before the Ordnance Board to explain his invention for the propulsion of balloons at a high rate of speed, and the same letter directed the Board to give to Mr. Thayer an interview, examine his plans, and make a report thereon to the Ordnance Office.

Mr. Thayer appeared before the Board and read a paper, herewith inclosed, describing his inventions, and also presented his patents, with specifications covering the same. The Board does not agree with Mr. Thayer as to the reasons given for the movement of his balloon, but after consideration of his plans deems them feasible and worthy of trial, in view of the great value and importance of such a machine for war purposes if it can be made to work practically. The trial in order to be complete and satisfactory should be made with a machine of a sufficient size to prove its efficiency under all ordinary circumstances. The Board therefore recommends that a machine of about 7 tons ascending force be constructed and trials be made with it. The cost of this machine complete is understood to be about $5,000.

T. G. BAYLOR,
Colonel of Ordnance, President of the Board.
GEO. W. McKEE,
Major of Ordnance.
CHARLES SHALER,
Captain of Ordnance.

A DESCRIPTION OF THAYER'S DIRIGIBLE BALLOON, SUITABLE FOR WAR PURPOSES—THE THEORY AND PRACTICAL OPERATION OF ITS MOTOR, ETC.

RUSSELL THAYER, C. E., Philadelphia.

It is only within recent years that the conditions of the problem of aerial navigation have been studied by engineers competent to deal with a matter of this description, and their investigations have proved that the navigation of the air is a question the solution of which is dependent upon the accomplishment of certain results quite within the range of applied mechanics of the present day.

Almost exactly one hundred years ago the discovery of the balloon solved one of the most difficult and important points in the problem, viz, the great obstacle to aerial operations caused by the action of the force of gravity upon all matter.

By means of the device of the balloon we are now enabled to overcome the force of gravity and to float in the atmosphere.

After this discovery the solution of the problem practically resolved itself into the discovery of means for applying force for the purpose of directing a balloon, properly designed in shape, on a regular course through the air in any given direction.

The extreme thinness and elasticity of the medium in which the body floats has baffled the ingenuity of the engineer and inventor in the application of a force for the propulsion of the aerial ship.

All methods of propulsion heretofore known have been tried and been found wanting. The idea, in every instance, has been to apply a surface of some resisting matter endowed with force against the air, the object in view being to obtain thereby a reactive force that would propel the air-ship through the atmosphere. Ignorant persons have suggested wheels, oars, and similar contrivances, while accomplished engineers, as De Lome and Gifford, have tried to adopt the propeller to the solution of the problem. All attempts heretofore made have practically been failures, although to Mr. Henri Gifford, the celebrated French engineer, the credit of first attempting to apply steam for the propulsion of a dirigible balloon can be given.

Another most important point in the final solution of the problem must be here referred to, viz, that it is only within the last few years that it has become possible to construct machinery of great power and extreme lightness combined with strength.

Mr. William Pole, F. R. S., M. Inst. C. E., in the year 1882 read a paper before the Institution of Civil Engineers of Great Britain, and discussed in a practical manner the problem of aerial navigation. The conclusions reached by him were as follows, viz:

(1) The problem of aerial navigation by balloons is one as perfectly amenable to mechanical investigation as that of aquatic navigation by floating vessels, and its successful solution involves nothing unreasonable or inconsistent with the teachings of mechanical science.

(2) It has been fully established by experiment that it is possible to design and construct a balloon which shall possess the conditions necessary for aerial navigation, viz, which shall have a form of small resistance, should be stable and easy to manage, and, if driven through the air, shall be capable of steering by a proper obedience of the rudder.

(3) Sufficient data exist to enable an approximate estimate to be made of the power necessary to propel such a balloon with any given velocity through the air.

(4) The recent reduction in the weight of steam-motors has rendered it possible to carry with the balloon an amount of power sufficient to produce moderately high speed, say 20 or 30 miles an hour through the air, and by taking advantage of other recent improvements it would also be possible to carry a moderate supply of fuel and water for the working.

(5) The practical difficulties in the way are only such as naturally arise in the extension of former successful trials, and such as may reasonably be expected to give way before skill and experience.

Mr. Pole's entire investigation of the subject, and the conclusions deducted, are based on the screw propeller as furnishing a practical means for the propulsion of an aerial ship.

A glance at the tabular results reached by him shows that as a means of applying the force generated, the steam-propeller is a most unsuitable and impracticable machine. Fancy a propeller 60 feet in diameter (the size required for a large aerial ship) and conveying a thrust of 3,000 pounds. The difficulties of constructing such an arrangement that would be of sufficient lightness and strength, and at the same time manageable, are insurmountable and preclude its use for the purpose in question.

The propeller is a most suitable contrivance for the propulsion of ships in heavy, incompressible fluid like water, especially where weight is no consideration, but is totally unsuited for the propulsion of bodies in an extremely attenuated and elastic medium as the air.

The conditions which obtain in regard to a body floating in the air are similar to those which exist in the case of a ship floating in the water. In both instances the structure is supported in the medium in which it floats, against the action of the force of gravity, by the weight of the fluid displaced, this weight acting vertically upwards in opposition to the force of gravity acting vertically downwards through the center of gravity. The force acting vertically upwards and sustaining the body in the fluid is called the "buoyant effort," and its intensity is equal to the weight of the fluid displaced. Its line of direction passes through the center of gravity of the displaced fluid, and this point is called the center of buoyancy. The following conclusions result from a thorough investigation of this branch of the subject, viz:

(1) The pressures upon the surface of a body immersed in a fluid have a single resultant called the "buoyant effort," and this resultant is directed vertically upwards.

(2) The buoyant effort is equal in intensity to the weight of the fluid displaced.

(3) The line of direction of the buoyant effort passes through the center of gravity of the displaced fluid.

(4) The horizontal pressures destroy one another.

In regard to the equilibrium of the floating body, I may state that it will be stable as long as the center of gravity of the body is below that of the displaced fluid. In the aerial ship that I have designed this condition will be always fulfilled, and consequently the structure cannot capsize.

Practical experiments and mathematical deductions prove that the best shape for the buoyant portion of the structure under discussion is that of a circular spindle in which $L = 3\frac{1}{4}\ d$, L representing the longer or horizontal axis and d the diameter amidships. This shape will give the least resistance to motion through the air, will comply with the conditions of stable equilibrium, and will give good steering qualities.

The ascending force of the gas, hydrogen being used, will be represented by the expression $A\ d^2\ l$, in which d and l represent quantities as above and A being a coefficient depending upon the shape of the vessel and on the specific gravity of the gas compared with that of the surrounding air. Supposing pure hydrogen gas to be used, the levity of 1 cubic foot = 0.0751 of a pound, and with the shape above given the ascending force determined by actual experiments may be represented by the expression $0.03\ d^2\ l$.

The resistance of the ship to motion through the air has been accurately determined by three methods, viz, by the midship-area calculation, skin-friction calculation, and cubic-displacement calculation; and based upon the conditions that $l = 3\frac{1}{4}\ d$, the following resistances have been obtained, viz:

By the midship area = $0.000172\ d^2\ v^2$
By the skin friction = $0.000173\ d^2\ v^2$
By the cubic displacement = $0.000211\ d^2\ v^2$

in which d represents as above and v = velocity in feet per second of time. Taking a mean of the two last expressions (the largest), the formula giving the resistance to the motion forward through the atmosphere becomes $X = 0.000193\ d^2\ v^2$

THE THEORY OF ACTION OF THE MOTOR.

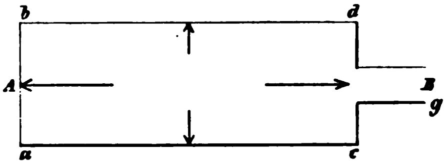
To return now to the subject of the propelling force, I will observe that the idea of beating the air (a medium of extreme rarity) with a propeller in order to generate a reactive force forward is impracticable, not only on account of the practical difficulties in the way as before suggested, but also and principally by reason of the unsubstantial character of the medium upon which the force is made to act and the great waste of power resulting from any such method. After careful investigation of the subject I was forced to adopt the conclusion that the propelling force must reside in the motor itself, and must be applied within itself in such a manner as to promote motion forward.

The action of the motor is entirely independent of extraneous conditions, and will produce high rates of motion without applying force against any extraneous resisting medium.

In all ordinary applications of force to produce motion we see the force generated applied against some resisting substance. The steamboat is propelled by the reaction resulting from the action of the blade of the paddles or screw upon the dense medium of the water. The locomotive engine moves forward by reason of the peripheries of the drivers rolling along the rail, but the tires must grip the rail before motion results. Numerous instances of the application of force based upon the principles here involved may be enumerated.

In the case of navigating the air, however, there is nothing upon which or against which the force generated can be applied. We are suspended in space, between heaven and earth, and if we except the invisible and extremely rare medium of the air, there is nothing upon which a propelling force can act extraneous to the machine itself. Under these circumstances we can only utilize the air as a medium, the weight of which causes a buoyant effort by which we can counteract the force of gravity and float. In order to move in the air I develop forces in unstable equilibrium, acting upon the structure itself, and producing a resultant power which will cause the ship to move in the direction in which said resultant is made to act.

The principles which I have adopted to produce this condition of continuous unstable equilibrium of forces may best be understood from the following simple demonstration:



Take a hollow cylinder, *abcd*, with an outlet at g=1 square inch in area. Now suppose this cylinder is kept constantly filled with air, steam, or vapor, under a pressure of, say, 100 pounds to each square inch; suppose the area of each cylinder-head = 10 square inches. Under these circumstances the total pressure on the head *a b* will = 10 by 100 = 1,000 pounds. On the head *c d* there will be only 9 square inches upon which the force within the cylinder can act; consequently the pressure on this end of the cylinder = 9 by 100 = 900 pounds. All the other forces within the cylinder are in a condition of equilibrium, for the reason that they are all acting, respectively, in directly opposite directions and are equal. Therefore, the resultant of forces = 1,000 pounds — 900 pounds = 100 pounds, acting in the direction B A, and this produces motion in that direction due to said resultant.

We have here generated a powerful force, and applied it in such a way as to produce motion with the simplest possible mechanism and entirely independent of extraneous conditions.

Motion can be produced by this principle in a perfect vacuum, remote from the reach and influence of all terrestrial objects; indeed, it is evident that in a vacuum the motion of a body impelled by the action of a force resident within the motor itself, by the principle above described, would be at a far higher rate of speed than would be the case in the air, for the reason that the medium in which the body is traveling, viz, the air, offers considerable resistance to motion due to friction.

The motor I have devised enables me to accumulate, produce, and apply an extremely powerful force. It consists essentially of a high-speed air-compressor coupled directly to a specially designed gas-engine, and a reservoir, called an accumulator, into which the compressed air is forced. The rear end of this reservoir is so arranged that at given intervals of time, a few seconds apart, the confined energy is suddenly released, thus producing a powerful motive thrust forward, due to the fact of the unstable condition of equilibrium of forces at the instant of discharge. The amount of power thus rendered available is dependent upon the size of the reservoir and its discharge. It is also, of course, a function of the time of charging and the number of strokes of the engine made therein. In the motor here described for aerial navigation the impact of the escaping air or vapor, under high pressure, against the particles of the surrounding air in which the body is floating, tends to increase the resultant action forward; but the principal portion of the motion forward is caused by the continuous condition of unstable equilibrium of forces producing a resultant action, as above described, in a given direction. The reaction resulting from the impact of the escaping gas upon the particles of the surrounding medium is small in comparison with the resultant of the forces in unstable equilibrium, but slight as it is it acts in the proper direction.

I regard the aperture at the rear of the motor mainly as a means for the escape of the wasted energy; its size is so proportioned as to produce the maximum condition of unstable equilibrium of forces.

I will now proceed to a description of the dirigible balloon, the plans of which accompany this paper. As will be seen from the drawings, it consists essentially of two portions. The buoyant part, which corresponds to the hull of a water ship, is made of superposed tissues of strong silk and rubber, and the shape is that of a circular spindle, in which the long horizontal axis = 3½ times the length of the diameter amidships; this structure is filled with hydrogen gas.

The deck of the ship, upon which the machinery is located, and where men with dynamite percussion cartridges or a Gatling gun can be placed, is below the buoyant part of the structure, and is firmly supported therefrom and braced thereto, as shown.

Opposite the center of the ship there is a lower deck, completely inclosed and separated from the rest of the structure, in which the power is located. From the cylinder of the motor a pipe leads all or part of the wasted energy utilized in the production of motion to the stern of the ship, and is there terminated by a nozzle fitted on a ball and socket joint. This arrangement permits the nozzle to be moved in any direction at pleasure, and by a movement of the nozzle from the wheel the ship may be steered in any direction that may be desired, thus avoiding the necessity for any rudder.

While the machinery is in motion and the force is being generated the ship is under perfect control and can be directed in any course that may be required. It is not necessary that the entire amount of wasted energy should be discharged at the stern of the ship and used for steering, and it is preferable not to do this, but to discharge the air or vapor near the motor and thus avoid the friction in the tube; a portion sufficient only to give good steering power should be taken to the nozzle at the stern.

In the interior of the buoyant portion of the ship is placed a large silk sack, connected with the air-compressor on the deck, and a pipe leads from the exterior envelope to the tube leading to the nozzle at the stern. Both of these pipes are provided with cocks, which can be opened or shut at pleasure.

There are four cylinders filled with compressed hydrogen on the deck of the ship, which are connected with the interior of the exterior envelope and are provided with cocks.

These appliances enable the aerial ship to travel at any elevation above the earth, and to ascend or descend in the atmosphere without the use of ballast. By simply withdrawing hydrogen from the interior of the exterior envelope and forcing air into the interior of the interior sack the buoyancy of the structure is diminished while its exterior form is not changed, and the ship will descend; the reverse of this operation will restore the original buoyancy and cause the ship to ascend. The importance of this matter will be appreciated when it is remembered that it is not proposed to travel habitually at high altitudes, but at elevations of a few hundred feet only, sufficient to clear terrestrial objects.

The following examples show the carrying capacities of aerial ships of various sizes, with the speed per hour and total resistance met with at the respective rates of motion; these elements are calculated from the formulas heretofore given in this paper:

In all cases *d* = diameter amidships, 1 = 3⅔*d* = length.

d = 30′ 1 = 110′

Total ascending force, 2,970 pounds.
Resistance, 10 miles per hour, 38.04+ pounds; 20 miles per hour, 149.11+ pounds.

d = 40′ 1 = 147′

Total ascending force, 7,040 pounds = 3½ tons.
Resistance, 10 miles per hour, 67.62 pounds; 20 miles per hour, 265.10 pounds.

d = 50′ 1 = 183′

Total ascending force, =13,725 pounds = say, 7 tons.
Resistance, 10 miles per hour, =105.66 pounds; =20 miles per hour, 414.22 pounds.

d = 75′ 1 = 275′

Total ascending force, 46,400 pounds = 23 tons.
Resistance, 20 miles per hour, 931.92 pounds; 40 miles per hour, 3,727.69 pounds.

d = 100′ 1 = 367′

Total ascending force, =110,000 pounds = 55 tons.
Resistance, 10 miles per hour, =422.67 pounds; 20 miles per hour, =1.656.90 pounds; 40 miles per hour, =6,627.62 pounds.

Note these resistances at the speed specified and observe how very small they are in comparison to the size of the aerial ship and its carrying capacity. It is only necessary for the motor to develop a force equal to the resistance, in any instance, to produce the corresponding rate of motion through the atmosphere.

The following table shows the speed in miles per hour that could be commanded on any proposed course by a ship having an independent motion through the air of 30 miles per hour, wind supposed due north, blowing with velocities varying from 0 to 50 miles per hour.

Velocity of wind.	N.	NNE. or NNW.	NE. or NW.	ENE. or WNW.	E. or W.	ESE. or WSW.	SE. or SW.	SSE. or SSW.	S.
Calm	30	30	30	30	30	30	30	30	30
5	25	25	26	27	29	31	34	35	35
10	20	20	22	25	28	33	37	39	40
15	15	15	17	20	25	32	39	44	45
20	10	10	13	16	22	31	41	48	50
25	5	5	7	9	17	29	43	51	55
30	....	....	....	....	....	22	43	56	60
35	....	....	....	....	....	....	42	59	65
40	....	....	....	....	....	....	38	63	70
45	....	....	....	....	....	....	....	67	75
50	....	....	....	....	....	....	....	70	80

The uses to which such a structure as I have described can be applied for war purposes are various. For communication with and relief of besieged towns it would be invaluable, and for all purposes of military observation and reconnaissance it would be very useful. For actual hostilities it could be employed as I have briefly suggested, viz, by sending a few men in a balloon of this description, in the day or night time, over a hostile town or fleet, and dropping down on to the enemy dynamite percussion cartridges. The effects would be very disastrous to the enemy, and there would be no way of avoiding the results.

A dynamite cartridge dropped on the deck of any form of ship would most probably sink her, or a Gatling gun can be used.

Of course there are other uses to which the structure that I have described could be devoted for military purposes. I simply have mentioned a few that have suggested themselves.

I feel satisfied from the experiments that I have made on a small scale that the apparatus is practical, and for a comparatively speaking small sum a war balloon can be built which would be exceedingly useful to the Government.

BALLOON OR AERIAL SHIP.

RUSSELL THAYER, of Philadelphia, Pa.

[Specification forming part of letters patent No. 309008, dated December 9,1884. Application filed November 23, 1883. (No model.)]

To all whom it may concern:

Be it known that I, Russell Thayer, of the city of Philadelphia, county of Philadelphia, and State of Pennsylvania, have invented an improvement in balloons or aerial ships, of which the following is a specification.

My invention has reference to balloons or aerial ships; and it consists in providing the same with devices to produce and maintain a supply of gas or vapor in a receiver and force the same from a discharging-nozzle at the rear of the balloon or air-ship under considerable pressure, whereby an unstable equilibrium of forces generated by the compressed gas or vapor in the receptacle is produced, and in details of construction, all of which are fully set forth in the following specification and shown in the accompanying drawings, which form part thereof.

The object of this invention is to provide a balloon or aerial ship with simple and effective means for navigating the same, irrespective of the air-currents in which it floats, whereby a great velocity is attained and the vessel made manageable; further, to dispense with the usual large wind-wheels or air-propellers, and all such devices which are bulky, unmanageable, and require a great power to work them.

In order to move in the air, I develop forces in unstable equilibrium acting upon the structure itself, and producing a resultant power which will cause the ship to move in the direction in which said resultant is made to act.

In the motor here described for aerial navigation the impact of the escaping air under high pressure against the particles of the surrounding air in which the body is floating tends to increase the resultant action forward; but the principal portion of the motion forward is caused by the continuous condition of unstable equilibrium of forces, producing a resultant action, as above described, in a given direction. The reaction resulting from the impact of the escaping gas upon the particles of the surrounding medium is small in comparison with the resultant of the forces in unstable equilibrium, but slight as it is it acts in the proper direction. I regard the aperture at the rear of the motor mainly as a means for the escape of the wasted energy. Its size is so proportioned as to produce the maximum conditions of unstable equilibrium of forces.

In the drawings, Figure 1 is a side elevation of my improved navigable aerial ship. Fig. 2 is a plan view of the upper or machine deck. Fig. 3 is a plan view of the lower or boiler deck, and Fig. 4 is an elevation (part in section) showing the mechanism for making the aerial ship rise or descend in the air.

A is the balloon proper or gas-receptacle, and is preferably made cigar-shaped and filled with hydrogen gas.

B is the net-work which surrounds the balloon A, and carries by ropes C the machine deck D, to the under part of which is supported the boiler-deck E.

F is the rudder, which may be formed like a mainsail of a yacht, and is moved by tiller-ropes G, which pass around blocks *g g*, and are secured to the tiller-wheel H in the forward part of the deck D.

I are the boilers or gas-holders and J is the smoke-pipe, which may extend downward, as shown, and deliver the smoke from the gas below the deck E, so as to allow the upper deck to remain clear and prevent injury to the silk or other material constituting the balloon proper.

K is a steam or gas air-compressor, in which air is compressed and delivered by a pipe, L, to a reservoir, M, under high pressure. From the reservoir M it is allowed to rush through the discharging nozzle N with any desired velocity, which is regulated by means of the valve *n*. If desired, the end N′ of the nozzle N may be hinged or pivoted on a universal joint, as at N^2, so that by setting said pivoted section at an angle the vessel may be quickly turned or made to travel in a curved line and raised or lowered at will. This may be used in conjunction with the rudder F, and will be advantageous, particularly when traveling with the wind.

In place of using the intermediate reservoir M, the air may be forced direct from the compressor into the discharging nozzle or pipe, which extends out of the rear of the ship and below the rudder; but by using a reservoir the pulsations of the discharged air due to the intermittent action of the compressor will not be felt by the ship, and as the air in the receiver exerts an equal and opposite pressure on all sides, except in the rear, where the discharging-nozzle is placed, and which, if it were not for said nozzle, would have been in stable equilibrium, is now unstable, the vessel is propelled with a force equal to the difference in pressure on the front and back of the said reservoir and the reactionary effect of the compressed air upon the atmosphere in its exit.

The exhaust-steam from the compressor K may be condensed in a condenser, O, and pumped back into the boilers I. The condenser may be kept cool by circulation of a refrigerating-liquid cooled in a refrigerator, P, and circulated by a pump, Q; or the steam may be condensed by a chemical refrigerator alone.

It is advisable to use the condensed steam, as the consumption of water would vary the burden of the vessel, and cause it to rise when not desired, and to prevent this it would be necessary to allow an equivalent of the hydrogen gas to escape. By using a gas-engine instead of a steam-engine we entirely avoid this difficulty, and we avoid entirely all danger from fire and the weight of water and coal or other fuel for the engine. The gas-fuel for the gas-engine is compressed, before starting, into a receiver.

To regulate the vertical travel of the balloon or ship in the air without varying the tension in the receptacle A, I provide the said receptacle with a smaller flexible eceptacle, A′, located within the larger.

R is a strong reservoir into which hydrogen gas is forced under very high pressure.

S is a compressor or force-pump, which may be operated by steam or hand power.

t is a pipe connecting with the receptacle or balloon A, and has two branches, t' t^2, provided with valves, one of which connects with the hydrogen tank R and the other with the suction of the compressor S.

W′ is an air-suction pipe for the compressor, and is also provided with a valve.

U is an air-pipe connecting the air receptacle A′ with the discharge of the compressor by a pipe, V, which is provided with a valve, and also with a discharge-pipe, W, provided with a valve, which pipe opens into the atmosphere. The discharge of the compressor is also connected by a valve-pipe, V′, with the hydrogen-tank R.

To ascend, air is allowed to escape by pipe W from vessel or bag A′, and hydrogen is passed into the receptacle A from tank R by pipes t' t until the receptacle A is filled out. To descend, hydrogen is allowed to escape into the atmosphere from balloon or receptacle A, or is drawn through pipes t t^2 and forced into the tank R by compressor S and pipe V′, and air is then sucked in pipe W′ and forced by compressor S through pipes V and U into bag A′ to fill out the receptacle A, as before.

In place of air, any other gas—as bisulphide-of-carbon vapor or carbonic oxide—may be forced through nozzle N.

I do not limit myself to the details of construction, as my invention comprehends the application of air, gas, or vapor kept in unstable equilibrium in a receiver and allowed to escape in the rear of an aerial ship in order to propel the same forward.

Having now described my invention, what I claim as new, and desire to secure by letters patent, is—

(1) The combination, in an aerial ship, of the hydrogen or gas receptacle made oblong or cigar-shaped, decks, ropes connecting said decks with said gas receptacle, boilers I, and air-compressor K, supported upon said decks, a discharging-pipe, N, extending rearward and connecting with said compressor, and the rudder F, arranged above said discharging-pipe and below the gas-receptacle, substantially as and for the purpose specified.

(2) The combination, in an aerial ship, of the hydrogen or gas receptacle, made oblong or cigar-shaped, decks, ropes connecting said decks with said gas-receptacle, boilers I, reservoir M, an air-compessor, K, supported upon said decks, a pipe connecting said reservoir with said compressor, a discharging-pipe, N, extending rearward and connecting with said compressor through said reservoir, and the rudder F, arranged above said discharging-pipe and below the gas-receptacle, substantially as and for the purpose specified.

(3) The combination of gas-receptacle A with the inner receptacle A′, a hydrogen-tank, R, a compressor, S, and connecting-pipes and valves by which the gas may be transferred to or from receptacle A and air to or from receptacle A′, substantially as and for the purpose specified.

(4) An aerial ship formed with an oblong or cigar-shaped gas-receptacle, and

supporting a reservoir into which air is forced under pressure, and an adjustable discharge-nozzle opening from the rear end of said reservoir and projecting rearwardly from the balloon or aerial ship, substantially as and for the purpose specified.

In testimony of which invention I hereunto set my hand.

RUSSELL THAYER.

Witnesses:
NATHL. E. JANNEY.
JOS. J. KNOX.

MOTOR.

RUSSELL THAYER, of Philadelphia, Pa.

[Specification forming part of Letters Patent No. 309,009, dated December 9, 1884. Application filed March 17, 1884. (No model.)]

To all whom it may concern:

Be it known that I, Russell Thayer, of the city and county of Philadelphia, and State of Pennsylvania, have invented an improvement in motors, of which the following is a specification.

My invention has reference to the propulsion of aerial ships, land vehicles, and marine vessels; and it consists in said aerial ships, vehicles, or vessels, provided with means to compress air, and an intermittent storage-reservoir having discharging-valves at one or both ends, said valves being intermittently operated to allow sudden discharges of the air or vapor compressed into said reservoir, whereby the forces of the air compressed in said reservoir when rendered unstable are enabled to react upon one end of said reservoir, to cause the said aerial ship, land vehicle, or marine vessel to be propelled. and in details of construction, all of which are fully set forth in the following specification, and shown in the accompanying drawings, which form part thereof. By forcing the air into a reservoir so constructed that when the pressure therein reaches a certain amount a large opening would be automatically provided for the instantaneous discharge or escape of the compressed air or vapor at one end of said reservoir a very great increase in propelling power can be rendered available, for the reason that at the instant previous to the discharge from the reservoir the forces generated therein by the compressed air or gas acting against its extensive internal surface will be in a condition of stable equilibrium, but at the instant the end of the reservoir is opened these forces on that end will be released, while those on the other end are still acting, consequently at that moment the reservoir would take up a motion due to the unsupported action on the closed end, and as the reservoir is a part of the motor and the motor is a part of the entire structure to be propelled, it will move in the direction opposite to that from which the spent energy is released. By varying the area of the discharge and the pressure of the compressed air any desired force may be produced for use in propelling.

In the drawings, Fig. 1 is a side elevation of an aerial ship having my improved motor attached thereto. Fig. 2 is a side elevation (with the reservoir in section) of my improved motor. Fig. 3 is a plan view of same. Fig. 4 is an end view of the reservoir, showing the discharge-ports. Fig. 5 is a plan view of the reservoir discharge-valves. Fig. 6 is an outline of a marine ship having my improved motor applied thereto; and Fig. 7 is a side elevation of a land vehicle having my improved motor applied thereto.

A represents the aerial ship, land vehicle, or marine vessel. B is the deck or floor upon which the motor is applied. C is the boiler; C′, the smoke-stack; D, the air-compressor; E, the intermittent storage-reservoir. The compressor D draws in air by valves *d* and discharges it by pipe F into the side of the reservoir E. This reservoir may be made in any manner desired, having one or both its heads G provided with discharge-valves. These heads G may have ports *g*.

H is a central shaft supported by the heads. Loosely supported upon this shaft H, and against the inner faces of heads G, are the circular valves I, having apertures *i*, to correspond with the openings *g* in the heads. These valves have clutch-hubs J. Upon the shaft H between the heads is a longitudinally-reciprocating sleeve, K, rotated or rocked with the shaft H by means of feathers *k′*. This sleeve is provided with circumferential groove K′ and a clutch, *k*, on each end, which are adapted to mesh with the clutches J on valves I. This sleeve may be moved longitudinally to mesh with either of said valves by an arm, L, secured to a rock-shaft, L′, and adapted to be rocked by a hand-lever, M, which may be set in either of its extreme positions by detent-pawl *m*, catching in notches *n* in segment N.

The shaft H may be intermittently rocked by hand or any suitable automatic mechanism—for instance, as shown—in which an arm O, is secured to the end of the shaft H outside the reservoir, and is drawn in one direction by a spring, O′, and pulled in the other by a bell-crank lever, S, pivoted to a frame, T, and having its free arm provided with a pin, *s*.

R is a ratchet-wheel, which is supported in a bearing, R′, and provided with a pin, *r*, on its face, which is arranged to strike the pin *s* during the rotation of said ratchet-wheel. This ratchet-wheel is rotated by the pawl P′, pivoted to a head or block, P, carried by the piston-rod D′, the said pawl being pressed against the ratchet-wheel by a spring, *p*. The ratchet-wheel R is prevented from rotating in the other direction by a pawl, P^2. As shown, there are twelve teeth to the ratchet-wheel; hence the compressor will make twelve double strokes to make one revolution of said ratchet-wheel, and during one of the intermittent movements of the ratchet-wheel the pin *r* thereon strikes the pin *s*, rocking the crank S and suddenly opening the valve I by causing the shaft H to be rocked. As shown, it is discharging from the rear end. If, now, it is desired to move backward, the hand-lever M is moved and the sleeve K moved until its clutch *k* meshes with the clutch J on the forward valve I, when any movement to shaft H causes the discharge to take place in the opposite direction. By this means a great and stable force may be generated in the reservoir, and which may in an instant be made unstable by the opening of one of the valves I, allowing the forces to act mainly on one end of the reservoir.

To guide the vessel, tubular extensions E′ may extend out of the reservoir E on each side, as shown in Fig. 3, and may be provided with valves *e*. By this means a constant discharge may be used, or the valves may be opened when the main discharge takes place to allow the unstable equilibrium of forces to come into play as well for steering as for propelling.

In the case of marine vessels, the air when leaving the reservoir E may be conveyed in all or part below the water by a pipe, G^2, (see Fig. 6,) to obtain the reactive force on the water as well as the resultant of the forces in the reservoir when the discharge takes place. The air in this instance may be controlled by a valve, Q, in the rear discharge-nozzle G′.

I do not limit myself to the details of construction, as they may be modified in various ways without departing from my invention.

Having now described my invention, what I claim as new, and desire to secure by Letters Patent, is—

(1) A motor consisting of means to compress air, in combination with a storage-reservoir and valved discharging-ports at one or both ends, substantially as and for the purpose specified.

(2) A motor consisting of means to compress air, in combination with a storage-reservoir and valved discharging-ports at one or both ends, and automatic mechanism to intermittently actuate said valves, substantially as and for the purpose specified.

(3) A motor consisting of means to compress air, in combination with a storage-reservoir and valved discharging-ports at one or both ends, and automatic mechanism controlled by the compressor to intermittently actuate said valves after a certain number of strokes, substantially as and for the purpose specified.

(4) A motor consisting of means to compress air, in combination with a storage-reservoir and valved discharging-ports at one or both ends and on its sides, substantially as and for the purpose specified.

(5) A motor consisting of means to compress air, in combination with a storage-reservoir having discharging-ports at each end, valves to open or close said ports, and mechanism to render either of said valves operative, but not both at the same time, substantially as and for the purpose specified.

(6) A motor consisting of means to compress air, in combination with a storage-reservoir having discharging-ports at each end, valves to open or close said ports, and mechanism to render either of said valves operative, but not both at the same time, and automatic mechanism to intermittently actuate said valve, substantially as and for the purpose specified.

(7) The combination of compressor D, pipe F, reservoir E, having discharging-ports *g*, valves I, having ports *i* and clutch-teeth J, shaft H, means to intermittently rock said shaft, sleeve K, having clutch-teeth *k*, and means to move said sleeve, substantially as for the purpose specified.

(8) The combination of compressor D, pipe F, reservoir E, having discharging-ports *g*, valves I, having ports *i* and clutch-teeth J, shaft H, means to intermittently rock said shaft, sleeve K, having clutch-teeth *k*, and means to move said sleeve, consisting of arm L, shaft L′, lever M, and means to lock said lever M in its extreme positions, substantially as and for the purpose specified.

(9) The combination of compressor D, pipe F, reservoir E, having ports *g*, valves I, having ports *i*, shaft H, arm O, lever S, having pin *s*, ratchet-wheel R, having pin *r*, piston-rod D′, and pawl P′, substantially as and for the purpose specified.

(10) The combination of the air-compressor D, pipe F, reservoir E, a discharging-valve, means to intermittently actuate said valve, and means to guide the discharged air in one or more directions, substantially as and for the purpose specified.

In testimony of which invention I hereunto set my hand.

RUSSELL THAYER.

Witnesses:

R. M. HUNTER,

FRANCIS S. BROWN.

PLATE I.

(No Model.)

2 Sheets—Sheet 2.

R. THAYER.

BALLOON OR AERIAL SHIP.

No. 309,008. Patented Dec. 9, 1884.

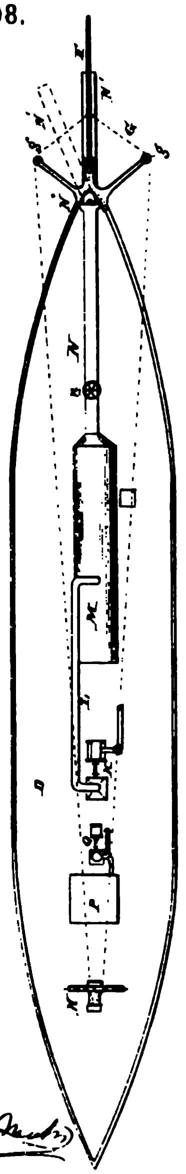


Fig. 2.

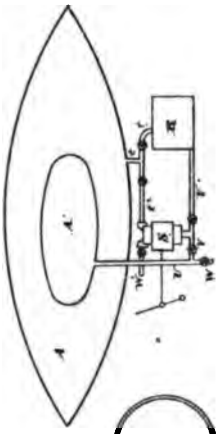


Fig. 4.

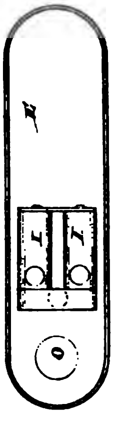


Fig. 3.

Inventor

Russell Thayer

By his atty.

Attest

Louis J. ...

A. McWade

Appendix 11—1885.

H Ex1 pt2 v3 49 1

PLATE II.

(No Model.)

2 Sheets—Sheet 1.

R. THAYER.

BALLOON OR AERIAL SHIP.

No. 309,008.

Patented Dec. 9, 1884.

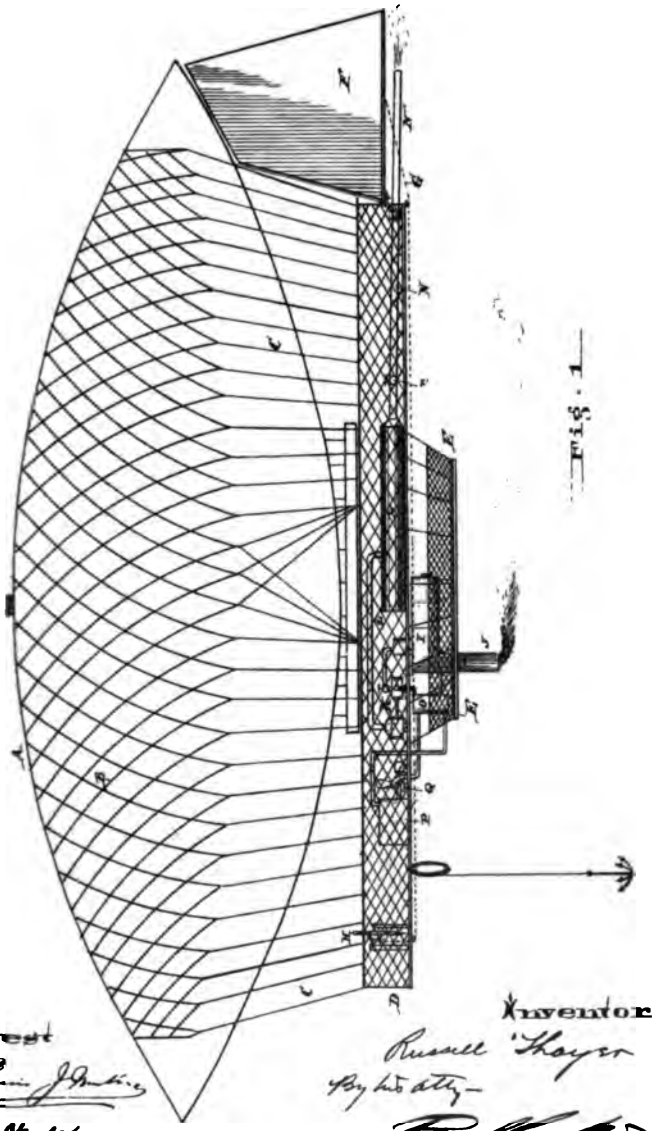


Fig. 1

Attest

H. McWade

Inventor

Russell Thayer

By his atty

H Ex1 pt2 v2 49 1

PLATE III.

(No Model.) 3 Sheets—Sheet 1.

R. THAYER.

MOTOR.

No. 309,009. Patented Dec. 9, 1884.

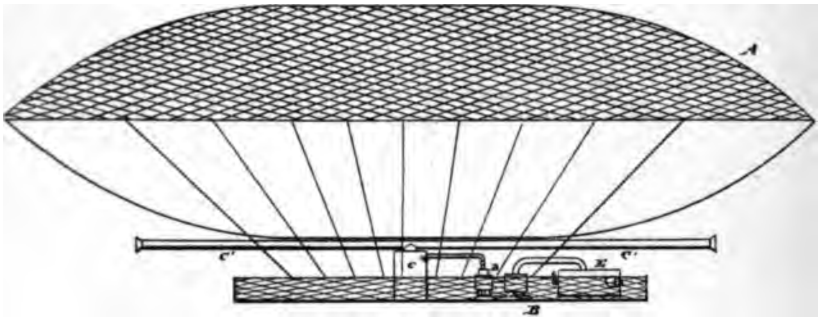


Fig. 1

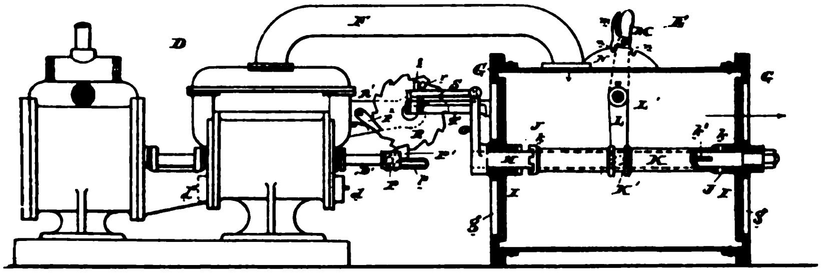


Fig. 2

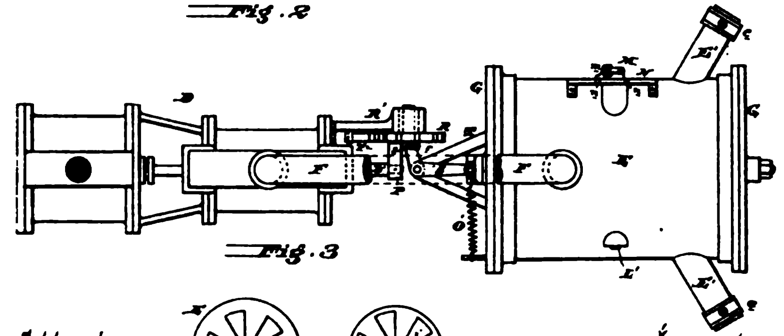


Fig. 3

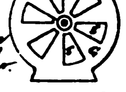


Fig. 4

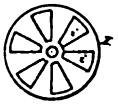


Fig. 5

Attest
William S. McHade
Harry R. Schafer.

Inventor
Russell Thayer
By his atty.

Appendix 11—1885.

H Ex1 pt2 v3 49 1

PLATE IV.

(No Model.) 3 Sheets—Sheet 2.

R. THAYER.

MOTOR.

No. 309,009. Patented Dec. 9, 1884.

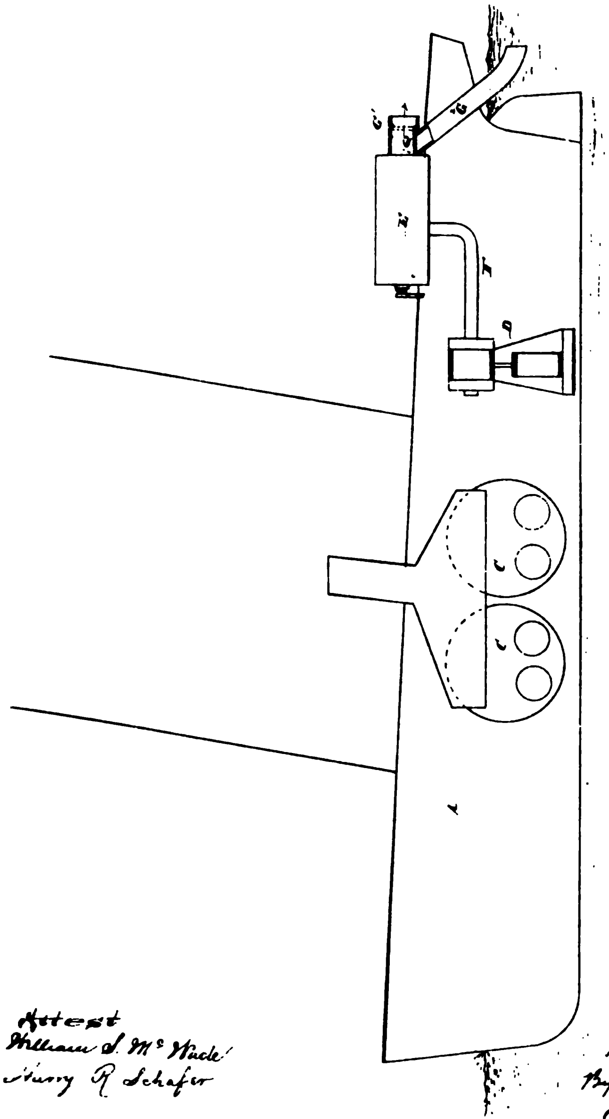


Fig. 6

Attest
William S. McWade
Harry R. Schafer

Inventor
Russell Thayer
By his atty.

H Ex1 pt2 v3 49 1

Appendix 11—1885.

PLATE V.

(No Model.)

3 Sheets—Sheet 3.

R. THAYER.

MOTOR.

No. 309,009.

Patented Dec. 9, 1884.

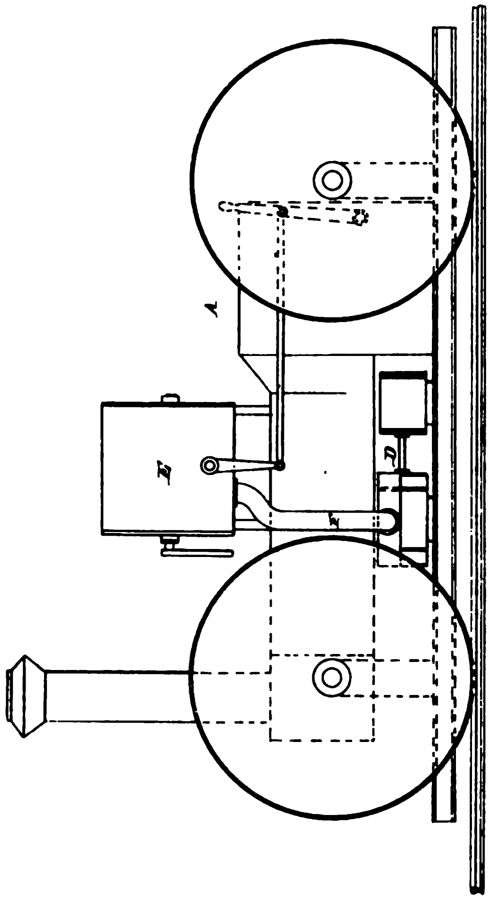


Fig. 1

Attest
William S. McHale
Harry R Schafer

Inventor
Russell Thayer
By his atty.

APPENDIX 12.

M. L. S. BUCKNER'S AERIAL DROP FOR EXPLOSIVES, BY THE ORDNANCE BOARD.

(1 plate.)

The following letter was received from the Chief of Ordnance January 24, 1885:

> Dr. M. L. S. Buckner, of Shelbyville, Ky., introduced by Senator Beck, is the inventor of a method of using high explosives from balloons.
>
> He will call at the New York Arsenal *next Saturday*, and the Board will give him an interview and examine his plans, reporting their opinion and what action, if any, should be taken by the Department in experimenting with the invention.

Dr. Buckner appeared before the Board January 24, 1885, with a model of his apparatus and explained its operations.

He subsequently sent to the Board a copy of his application for a patent, giving a drawing and specifications which is herewith appended. He desires that this be kept secret for the present.

The machine is ingenious and there seems to be no doubt that it will work and drop its explosives at the fixed time to which the alarm-clock may be set. The machine has to be suspended from a balloon, and to be efficient would require a very accurate knowledge of the force and direction of the wind at different elevations, and of course at best could only be used under the most favorable circumstances and when the wind was blowing in the direction of the object to be reached. The Board is not sufficiently versed in the science of aerostation to express an opinion as to the probable accuracy with which a balloon can be estimated to reach a given point and the length of time required to do so.

The Board would therefore suggest that this matter be referred to some one who has made a study of this subject.

T. G. BAYLOR,
Colonel of Ordnance, President of the Board.
GEO. W. McKEE,
Major of Ordnance.
CHARLES SHALER,
Captain of Ordnance.

SPECIFICATION FORMING PART OF APPLICATION FILED SEPTEMBER 17, 1884, BY MOSES L. S. BUCKNER FOR AERIAL DROPS FOR EXPLOSIVES.

[Allowed October 4, 1884.]

To all whom it may concern:

Be it known that I, Moses L. S. Buckner, a citizen of the United States, residing at Shelbyville, in the county of Shelby and State of Kentucky, have invented a new and useful improvement in aerial drop for explosives, of which the following is a description.

This invention relates to aerial transportation of explosives and dropping them in warfare; and it has for its object to reach the enemy with destroying agents at distances greater than may be done by any present known method of throwing projectiles.

To this end my invention consists in the construction and combination of parts forming the aerial drop for explosives hereinafter described and claimed, reference being had to the accompanying drawings, in which Fig. 1 is a front view of my invention and Fig. 2 shows the principal parts in detail.

A represents a frame of any suitable form to support a common time-keeping clock, B, and my explosive dropping arrangements, and to be supported by a balloon, C. D is a belt or chain mounted to rotate on pulleys E F. The pulley E is a mere roller, and it may be journaled on a level with the pulley F, so as to cause the belt to traverse horizontally; or it may be journaled above the pulley F, causing the belt to travel vertically. G G are buckets or other receptacles for carrying explosives in any suitable form. These receptacles may hang sideways against the belt, as at G′, or they may sit flat upon the belt, as at G″. In either case the revolving of the belt tips the buckets to discharge their contents as each passes over one of the pulleys. The receptacles may be arranged in any desired order on the belt, either clustered together or equally spaced over its entire length. The pulley F is connected by a train of gear-wheels with a propelling-spring, H, its rate of revolution being governed by a fan-wheel, I, whose blades being resisted by the air are restricted to a given speed.

This portion of the device is common clock-work, such as is used for similar purposes, and it is here called "propelling mechanism." This propelling mechanism, after being wound up, remains fixed until the clock-hands arrive at the figures indicating the time at which the device has been previously set to start; then it starts to revolve and continues to revolve until the contents of the receptacles G are emptied—that is, until the belt D has made a complete revolution. The shaft of the driving-pulley F would start at once to revolve as soon as the spring H is wound up, but its revolution is prevented in the same manner as the alarm of a clock is prevented from operating until a given time. J represents the time-hand of the starting device, and K is the knob by which it is set. In service my aerial dropper for explosives will be managed according to the rules of scientific gunnery and engineering.

The speed and course of the wind and the distance to the enemy being ascertained, it only remains to locate the starting-point in the proper line, set the time-escapement to the number of minutes or hours required for the balloon to travel that distance, then start the balloon. Dynamite and such like powerful explosives may be thus dropped upon the enemy from overhead, where he is least protected.

A fort, an army, or vessels may be thus destroyed by means wholly irresistible.

What I claim as my invention, and desire to secure by letters patent, is:

1. The combination, with a series of explosive carrying-receptacles arranged to empty their contents in rotation, and means for rotating them, of clock-work connected with said means of rotation to start it to rotating at any given time and a balloon for carrying the said apparatus.

2. The combination, with the frame A, and the pulleys E and F, journaled therein, of the belt D, mounted to rotate on the pulleys, the receptacles G, attached to the belt, the spring H, and gear-wheels connecting it with the driving-pulley F, the clock B, provided with the setting-knob K and time-hand J, means connecting the clock with the pulley F, the balloon C, supporting the frame A, and attachments, substantially as shown and described, whereby explosives may be transported through the air for a given length of time and then be dropped, as specified.

The above specification of my invention signed by me in the presence of two subscribing witnesses.

MOSES L. S. BUCKNER.

Witnesses:

W. X. STEVENS.
SOLON C. KERNON.

PLATE I.

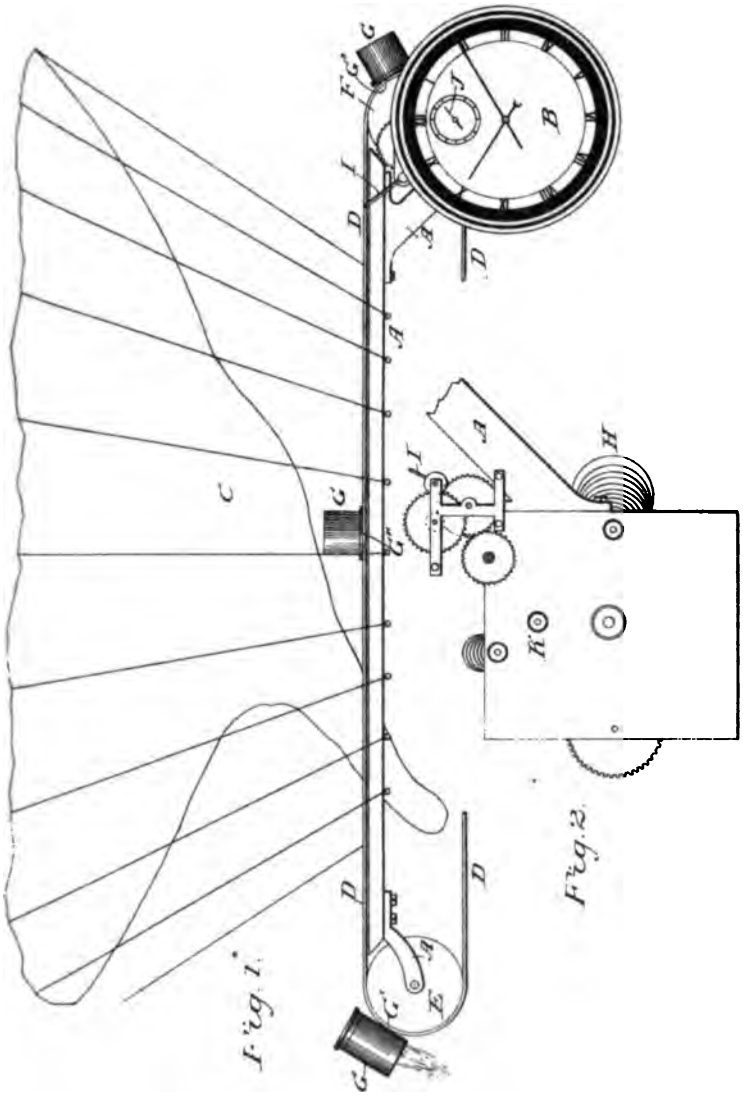


Fig. 1.

Fig. 2.

Appendix 12—1885.

APPENDIX 13.

FIRINGS WITH HOTCHKISS MOUNTAIN GUN. BY THE ORDNANCE BOARD.

(2 plates.)

The gun, its carriage and ammunition are described and illustrated in the Report of the Chief of Ordnance for 1881, page 133, *et seq.*

The experiments tabulated below were carried on by order of the Chief of Ordnance given in an indorsement dated December 9, 1884, on a letter from B. B. Hotchkiss. This letter states that the report above referred to gives too high a velocity for the projectile and charge of powder used. Examination of the report shows that the weight of the projectile is recorded as 2 pounds 10 ounces, whereas it should have been given as 2 pounds. The other data of the report on this subject are correct. An inclosure to the letter of Mr. Hotchkiss gave a schedule of work required and field data to be obtained for computing a range table for the mountain gun and supplied a form according to which it was desired that the records might be furnished. The firing records in the usual form are furnished with this report, and the same records arranged as desired by Mr. Hotchkiss are as follows:

Trials conducted between January 30 *and February* 20, 1885, *under instructions from the Chief of Ordnance dated December* 9, 1884, *with the Hotchkiss* 42-*millimeter mountain gun.*

[1st. Object of trial; the determination of velocities at 100 and 550 feet from muzzle with deviations from center of impact.]

CONDITIONS OF FIRING.

Projectile: Cast-iron shell weighted to 1 pound 15 ounces.
Charge: Powder, Du Pont's H N; density, 1.607; granulation, 229.30; weight, 5¼ ounces.
Pointing: Inclination + 2′.
Wind: Direction, front and right, 48° (angles read from the line of fire in each quadrant); force, 5.9 feet.
Barometer, 30″.315; thermometer, 27°.3; wet bulb, 24°.2; dew point, 16°.9.

The gun on its carriage was fired from a plank walk, occupying precisely the same position for each round; the service sights of the gun were used in pointing, but elevations were given with the quadrant. The board target was distant from the muzzle 620 feet, and its bull's-eye was 0.9 feet above axis of trunnions of gun. No. 32 wire was used on the velocity targets. The powder charges were weighed out on scales recording one-fourth grains.

Number of round.	Angle of elevation.	Velocity at 100 feet.	Velocity at 550 feet.	Deviations.							
				From center of target.				From center of impact.			
				Vertical.		Horizontal.		Vertical.		Horizontal.	
				Above.	Below.	Right.	Left.	Above.	Below.	Right.	Left.
		Feet.	*Feet.*	*Feet.*	*Feet.*	*Feet.*	*Feet.*	*Feet.*	*Feet.*	*Feet.*	*Feet.*
1	+2′	1,276	1,193	0.10	....	0.19	....	0.262	....	....	0.029
2	+2′	1,274	1,192	....	0.50	....	0.07	....	0.328	....	0.289
3	+2′	1,270	1,181	0.93	....	....	0.21	1.092	...	....	0.429
4	+2′	1,279	190	....	0.38	0.71	....	....	0.218	0.491	....
5	+2′	1,275	1,187	....	0.68	0.08	....	....	0.518	....	0.139
6	+2′	1,279	1,185	....	0.33	0.11	....	....	0.168	....	0.109
7	+2′	1,276.5	1,183	0.24	....	0.66	....	0.402	....	0.441	....
8	+2′	1,283	1,193	0.31	....	0.81	....	0.472	....	0.591	....
9	+2′	1,280	1,179	....	0.70	0.86	....	....	0.538	0.641	....
10	+2′	1,283	1,189	....	0.61	....	0.95	....	0.448	....	1.169
				1.58	3.20	3.42	1.23	2.228	2.228	2.164	2.164
				1.62+10=0.162		2.19+10=0.219		4.456+10=0.45		4.328+10=0.43	

Mean vertical deviation from center of impact.......... 0′.45
Mean horizontal deviation from center of impact.......... 0′.43
Mean deviation from center of impact.......... 0′.63

[Number of shots, 10.]

		At 100 feet.	At 550 feet.
V	Mean velocity..........	1,277.6	1,187.2
V_M	Maximum velocity..........	1,283	1,193
Vm	Minimum velocity..........	1,270	1,179
V_M—m	Variation..........	13	14
Em	Mean variation..........	3.25	4.20
Vo..........		....	....

[2. **Object of trial: Range firing over the sea at 3° and 6° elevation; measurement of ranges; drift and time of flight.**]

CONDITIONS OF FIRING.

Projectile: Cast-iron shell weighted to 1 pound 15 ounces.

Charge: Powder, Du Pont's H N; density, 1.607; granulation, 22930; weight, 5¼ ounces.

Pointing: Inclination, 1st series, 3°; 2d series, 6°.

Wind: Direction, rear and left, 55°; force, 5.9 feet.

Barometer, 30″.184; thermometer, 28.1; wet bulb, 25°.6; dew point, 20°.1.

Gun fired from plank walk. Elevations given with quadrant, and as recorded, not corrected for angle of jump or difference of level. Ranges plotted by plane-tables.

[Angle of elevation 3°. Axis of trunnions of gun 13.95 feet above sea-level.]					[Angle of elevation 6°. Axis of trunnions of gun 13.33 feet above sea-level.]				
Number of shot.	X yards.	D yards.		T seconds.	Number of shot.	X yards.	D yards.		T seconds.
		Left.	Right.				Left.	Right.	
1	1,471	3	....	4.5	1	2,346	16	....	8.0
2	1,480	8	....	4.5	2	2,345	14	....	7.75
3	1,467	3	....	4.4	3	2,342	13	....	7.75
4	1,467	3	....	4.5	4	2,361	14	....	8.25
5	1,494	5	....	4.5	5	2,342	13	....	8.0
6	1,479	4	....	4.5	6	2,335	11	....	7.8
7	1,475	3.75	....	4.5	7	2,327	11	....	7.75
8	1,493	5	....	4.5	8	2,352	12	....	8.0
9	1,464	2.75	....	4.5	9	2,267	10	....	7.75
10	1,480	8	....	4.5	10	2,312	10.5	....	8.0

Angle		3°	6°
Number of shots		10	10
X	Mean range ... yards..	1,477	2,333
X_M	Maximum range ... yards..	1,494	2,361
X_m	Minimum range ... yards..	1,467	2,267
X_{M-m}	Extreme deviation ... yards..	27	94
Q	Mean longitudinal deviation ... yards..	8.2	18.6
R	Ratio of mean deviation to mean range	0.0055	0.0079
X'	True range ... yards..	...	...
D	Mean drift ... yards..	4.6	12.5
D_M	Maximum drift ... yards..	8	16
D_m	Minimum drift ... yards..	2.75	10
D_{M-m}	Extreme deviation of drift ... yards..	5.25	6
g	Mean drift deviation ... yards..	1.57	1.55
r	Ratio of mean drift to mean range ...	0.0031	0.0054
D'	True drift ... yards..	...	...
T	Mean time ... seconds..	4.49	7.83
T_M	Maximum time ... seconds..	4.5	8.25
T_m	Minimum time ... seconds..	4.4	7.75
T_{M-m}	Variation of time ... seconds..	0.1	0.5

Object of trial: Range firing over the sea at 9° and 12° elevation; measurement of ranges; drift and time of flight.]

CONDITIONS OF FIRING.

***Projectile*:** Cast iron shell weighted to 1 pound 15 ounces.
***Charge*:** Powder, Du Pont's H N; density, 1.607; granulation, 22.930; weight, 5¼ ances.
***Pointing*:** Inclination, 1st series, 9°; 2d series, 12°.
***Wind*:** Direction, rear and right, 34°; force, 14.7 feet.
Barometer, 29''.916; thermometer, 25.1; wet bulb, 23°.3; dew point, 19°.0.

Gun fired from plank walk. Elevations given with quadrant, and as ecorded, not corrected for angle of jump or difference of level. Ranges lotted by plane-tables.

[Angle of elevation 9°. Axis of trunnions of gun 13.8 feet above sea-level.]					[Angle of elevation 12°. Axis of trunnions of gun 14.55 feet above sea-level.				
Number of shot.	X yards.	D yards.		T seconds.	Number of shot.	X yards.	D yards.		T seconds.
		Left.	Right.				Left.	Right.	
1	2,982	11.75	....	11	1	3,592	13.25	....	14
2	2,989	12.50	....	Lost.	2	3,589	17.5	....	14.13
3	2,989	12.50	....	11	3	3,596	9	....	13.75
4	2,985	14.5	....	11	4	3,604	14	....	14.0
5	2,996	13.25	....	11.25	5	3,614	14.5	....	14
6	3,002	13.75	....	11	6	3,569	12	....	13.75
7	2,996	13.25	....	10.75	7	3,567	16.75	....	13.75
8	3,012	16.75	....	11	8	3,626	14.75	....	14.0
9	2,998	15.5	....	11	9	3,626	14.75	....	14.0
10	2,998	15.5	....	11	10	3,569	12	....	14.0

Angle		9°	12°
Number of shots		10	10
X	Mean range ... yards..	2,995	3,595
X_M	Maximum range ... yards..	3,012	3,626
X_m	Minimum range ... yards..	2,982	3,567
X_{M-m}	Extreme deviation ... yards..	30	59
Q	Mean longitudinal deviation ... yards..	6.7	18.0
R	Ratio of mean deviation to mean range	0.00224	0.005
X'	True range ... yards..	...	...
D	Mean drift ... yards..	13.93	14.85
D_M	Maximum drift ... yards..	16.75	17.5
D_m	Minimum drift ... yards..	11.75	9
D_{M-m}	Extreme deviation in drift ... yards..	5.0	8.5
g	Mean drift deviation ... yards..	1.31	1.9
r	Ratio of mean drift to mean range ...	0.00465	0.0039
D'	True drift ... yards..	...	...
T	Mean time ... seconds..	11	13.94
T_M	Maximum time ... seconds..	11.25	14.13
T_m	Minimum time ... seconds..	10.75	13.75
T_{M-m}	Variation of time ... seconds..	0.5	0.38

[4. Object of trial; the determination of the angle of jump at 0°, 3°, 6°, 9°, and 12°.]

CONDITIONS OF FIRING.

[Projectile: Cast-iron shell weighted to 1 pound 15 ounces. Charge: Powder, Du Pont's H. N.; density 1.607; granulation, 22930; weight, 5¼ ounces.]

	First series.	Second series.
Pointing: Inclination .... degrees..	0 and 3	6, 9, and 12
Wind:		
Direction from rear and right ...... do.....	43	....
Direction from rear and left .... do.....	....	3
Force .... feet..	29.3	35.2
Barometer .... inches..	29, 969	29, 953
Thermometer .... degrees..	19.9	14.8
Wet bulb .... do	17.1	12.8
Dew point .... do	7.8	5.6

Gun fired from plank walk at target distant 100 feet. Elevations given with quadrant and gun sighted by cross hairs in bore of gun.

Number of shots.	Elevation.	Angle of jump.
	Degrees.	′ ″
3.................	0	15–51
3.................	3	22–23
3.................	6	22–48
3.................	9	19–40
3.................	12	17–18

NOTE.—X' D' V_0 are not calculated, but the data called for from which they may be obtained are all given.

T. G. BAYLOR,
Colonel of Ordnance, President of the Board.
GEO. W. McKEE,
Major of Ordnance.
CHARLES SHALER,
Captain of Ordnance.

Record of firing with Hotchkiss 42-millimeter mountain gun

	No. of fire.	Time.	Powder.		Projectile.			Elevation.	Instrumental velocity at 550 feet from gun.	Instrumental velocity at 100 feet from gun.	Recoil.	Wind, strength and direction.
			Kind.	Weight, ounces.	Kind.	Wt. Pounds.	Wt. Ounces.					
		1885.						°	*Feet.*	*Feet.*	*Feet.*	
P. M.—Barometer, 29.903; thermometer, 31.9; humidity, 67.	1	Jan. 21	Du Pont's E. Z. A. Density, 1.750; granulation, 31,232.	6	Hotchkiss (with point fuze).	1	15	0	......	Lost.	......	From rear and right 87°; 18 miles an hour.
	2	Jan. 21		6		1	15	0	......	1,225	......	
	3	Jan. 21		6		1	15	0	......	1,226	......	
	4	Jan. 21		6		1	15	0	......	1,224	......	
	5	Jan. 21		6		1	15	0	......	1,240	......	
	6	Jan. 21		6		1	15	0	......	1,232	......	
	7	Jan. 21	Du Pont's K. E. A. Density, 1.746; granulation, 25,848.	6		1	15	0	......	1,226	......	
	8	Jan. 21		6		1	15	0	......	1,213	......	
	9	Jan. 21		6		1	15	0	......	1,215	......	
	10	Jan. 21		6		1	15	0	......	1,210	......	
	11	Jan. 21		6		1	15	0	......	1,195	......	
A. M.—Barometer, 30.457; thermometer, 12.9; humidity, 70.	12	Jan. 22	Laflin & Rand cannon. Density, 1.75071; granulation, 49,590.	5½		1	15	0	......	Lost.	......	From rear and left 3°; 30 miles an hour.
	13	Jan. 22		5½		1	15	0	......	1,262	......	
	14	Jan. 22		5½		1	15	0	......	1,294	......	
	15	Jan. 22		5½		1	15	0	......	1,272	......	
	16	Jan. 22		5½		1	15	0	......	1,269	......	
	17	Jan. 22		5½		1	15	0	......	1,277	......	
	18	Jan. 22	Du Pont's H. N. Density, 1.607; granulation, 22,930.	5½		1	15	0	......	1,321	......	
	19	Jan. 22		5½		1	15	0	......	1,323	......	
	20	Jan. 22		5½		1	15	0	......	1,312	......	
	21	Jan. 22		5½		1	15	0	......	1,323	......	
	22	Jan. 22		5½		1	15	0	......	1,328	......	
A. M.—Barometer, 30.584; thermometer, 21.7; humidity, 77.	23	Jan. 23		5½		1	15	2	1,207	Lost.	......	From front and right 48°; 3 miles an hour.
	24	Jan. 23		5½		1	15	2	1,245	1,335	......	
	25	Jan. 23		5½		1	15	2	Lost.	1,333	......	
	26	Jan. 23		5½		1	15	2	1,232	1,330	......	
	27	Jan. 23		5½		1	15	2	Lost.	1,346	......	
	28	Jan. 23		5½		1	15	2	Lost.	1,344	......	
	29	Jan. 23		5½		1	15	2	1,278	1,382	......	

at Sandy Hook, N. J., from January 21 *to February* 20, 1885.

Special remarks about each fire, such as effect on piece, sound of projectile in flight, scattering of fragments, &c.

Fired into sand butt.

Distance from center of target, in feet.				Distance from center of impact, in feet.			
Vertical.		Horizontal.		Vertical.		Horizontal.	
Above.	Below.	Right.	Left.	Above.	Below.	Right.	Left.
....	0.20	....	1.00	....	0.13	....	0.96
....	0.92	....	0.75	....	0.85	....	0.71
1.17	....	2.71	....	1.24	....	2.75	....
....	0.81	....	0.41	....	0.74	....	0.37
0.81	....	....	....	0.88	....	0.04	....
0.50	....	0.08	....	0.57	....	0.12	....
....	1.04	....	0.91	....	0.97	....	0.87
2.48	2.97	2.79	3.07	2.69	2.69	2.91	2.91
0.49+7=0.07		0.28+7=0.04		5.38+7=0.77		5.82+7=0.83	

Target 620 feet from gun; target 6'×7', made of 1" spruce boards.

Height of bull's eye of target above axis of trunnion of gun, 0.9 feet.

Mean vertical deviation from center of impact, 0'.77.

Mean horizontal deviation from center of impact, 0'.83.

Mean deviation from center of impact, 1'.13.

Record of firing with Hotchkiss 42-millimeter mountain gun No. 64, at

	No. of fire.	Time.	Powder. Kind.	Powder. Weight, ounces.	Projectile. Kind.	Projectile. Wt. Pounds.	Projectile. Wt. Ounces.	Elevation.	Instrumental velocity at 550 feet from gun.	Instrumental velocity at 100 feet from gun.	Recoil.	Wind, strength and direction.	Angle of jump.
		1885.						° ′	*Feet.*	*Feet.*	*Feet.*		′ ″
Weight of cubic foot of air, 573.9 (Glaisher's tables). A. M.—Barometer, 30.315; thermometer, 27.3; humidity, 63.	30	Jan. 30	Du Pont's H. N. Density, 1.607. Granulation, 22,930.	5½	Hotchkiss (with point fuze).	1	15	2	Lost.	1,261	18.00	From front and right 28°; 4 miles an hour.	......
	31	Jan. 30		5½		1	15	2	Lost.	1,280	18.00		......
	32	Jan. 30		5½		1	15	2	1,193	1,276	18.00		......
	33	Jan. 30		5½		1	15	2	1,192	1,274	18.00		......
	34	Jan. 30		5½		1	15	2	1,181	1,270	18.00		......
	35	Jan. 30		5½		1	15	2	1,190	1,279	18.00		......
	36	Jan. 30		5½		1	15	2	1,187	1,275	18.00		......
	37	Jan. 30		5½		1	15	2	1,185	1,279	18.00		......
	38	Jan. 30		5½		1	15	2	1,183	1,276.5	18.00		......
	39	Jan. 30		5½		1	15	2	Lost.	Lost.	18.00		......
	40	Jan. 30		5½		1	15	2	1,193	1,283	18.00		......
	41	Jan. 30		5½		1	15	2	1,179	1,280	18.00		......
	42	Jan. 30		5½		1	15	2	Lost.	1,273	18.00		......
	43	Jan. 30		5½		1	15	2	Lost.	1,278	18.00		......
	44	Jan. 30		5½		1	15	2	1,189	1,283	18.00		......
Weight of cubic foot of air, 570.7. P. M.—Barometer, 30.184; thermometer, 28.1; humidity, 70.	45	Jan. 30		5½		1	15	3	......	......	From 18 to 21 feet.	From rear and left 55°; 4 miles an hour.	......
	46	Jan. 30		5½		1	15	3	......	......			......
	47	Jan. 30		5½		1	15	3	......	......			......
	48	Jan. 30		5½		1	15	3	......	......			......
	49	Jan. 30		5½		1	55	3	......	......			......
	50	Jan. 30		5½		1	15	3	......	......			......
	51	Jan. 30		5½		1	15	3	......	......			......
	52	Jan. 30		5½		1	15	3	......	......			......
	53	Jan. 30		5½		1	15	3	......	......			......
	54	Jan. 30		5½		1	15	3	......	......			......

Sandy Hook, N. J., from January 21 to February 20, 1885—Continued.

Distance from center of target, in feet.				Distance from center of impact, in feet.				Special remarks about each fire, such as effect on piece, sound of projectile in flight, scattering of fragments, &c.
Vertical.		Horizontal.		Vertical.		Horizontal.		
Above.	Below.	Right.	Left.	Above.	Below.	Right.	Left.	
....	1.06	....	0.60	....	0.78	....	0.47	Fired at target 620 feet from gun. Target 6' by 7', made of 1" spruce boards. From this round the powder charges were weighed on scales measuring ½ grains, while previously scales were used which only recorded $\frac{1}{16}$ ounce. Height of bull's-eye of target above axis of trunnion of gun, 0.9 feet.
....	0.22	....	0.94	0.06	....	....	0.81	
0.10	....	0.19	....	0.38	....	0.32	....	
....	0.50	....	0.07	....	0.22	0.06	....	
0.93	....	....	0.21	1.21	....	....	0.08	
....	0.38	0.71	....	....	0.10	0.84	....	
....	0.68	0.08	....	....	0.40	0.21	....	
....	0.33	0.11	....	....	0.05	0.24	....	
0.24	....	0.66	....	0.52	....	0.79	....	
....	1.35	....	1.37	....	1.07	....	1.24	
0.31	....	0.81	....	0.59	....	0.94	....	
....	0.70	0.86	....	....	0.42	0.99	....	
0.33	....	....	1.10	0.61	....	....	0.97	
Short.	Short.	Short.	Short.	Short.	Short.	Short.	Short.	
....	0.61	....	0.95	....	0.33	....	0.82	
1.91	5.83	3.42	5.24	3.37	3.37	4.39	4.39	
3.92+14=0.28		1.82+14=0.13		6.74+14=0.48		8.78+14=0.63		

Mean vertical deviation from center of impact................ 0'.48.
Mean horizontal deviation from center of impact .... 0'.63.
Mean deviation from center of impact.......................... 0'.80.

Time of flight.	Range.	Deflection.
Seconds.	*Yards.*	*Yards.*
4½	1,471	3 left.
4½	1,480	8 left.
4$\frac{6}{10}$	1,467	3 left.
4½	1,467	3 left.
4½	1,494	5 left.
4½	1,479	4 left.
4½	1,475	3¾ left.
4½	1,493	5 left.
4½	1,464	2¾ left.
4½	1,480	8 left.

Fired to sea for ranges.

Height of axis of trunnion of gun above mean low-water mark, 15.1 feet.

Axis of gun 13.95 feet above sea-level.

Record of firing with Hotchkiss 42-millimeter mountain gun No. 64 at

	Number of fire.	Time.	Powder. Kind.	Powder. Weight, ounces.	Projectile. Kind.	Projectile. Wt. Pounds.	Projectile. Wt. Ounces.	Elevation.	Instrumental velocity at 550 feet from gun.	Instrumental velocity at 100 feet from gun.	Recoil.	Wind, strength, and direction.	Angle of jump.
		1885.						°	*Feet.*	*Feet.*	*Feet.*		' "
Weight of cubic foot of air, 570.7. P. M.—Barometer, 30.184; thermometer, 28.1; humidity, 70.	55	Jan. 30	Du Pont's H. N. Density, 1.607. Granulation, 22, 930.	5⅛	Hotchkiss (with point fuze).	1	15	6	......	....	From 18 to 21 feet.	From rear and left 55°; 4 miles an hour.	......
	56	Jan. 30		5⅛		1	15	6	......	....			......
	57	Jan. 30		5⅛		1	15	6	......	....			......
	58	Jan. 30		5⅛		1	15	6	......	....			......
	59	Jan. 30		5⅛		1	15	6	......	....			......
	60	Jan. 30		5⅛		1	15	6	......	....			......
	61	Jan. 30		5⅛		1	15	6	......	....			......
	62	Jan. 30		5⅛		1	15	6	......	.... ..			......
	63	Jan. 30		5⅛		1	15	6	......	....			......
	64	Jan. 30		5⅛		1	15	6	......	....			......
Weight of cubic foot of air, 567.5. P. M.—Barometer, 29.916; thermometer, 25.1; humidity, 76.	65	Feb. 3		5⅛		1	15	9	......	.... ..	13.00	From rear and right 34°; 10 miles an hour.	......
	66	Feb. 3		5⅛		1	15	9	......	....	13.50		......
	67	Feb. 3		5⅛		1	15	9	......	....	12.50		......
	68	Feb. 3		5⅛		1	15	9	......	....	13.00		......
	69	Feb. 3		5⅛		1	15	9	......	....	12.50		......
	70	Feb. 3		5⅛		1	15	9	......	....	12.25		......
	71	Feb. 3		5⅛		1	15	9	......	....	12.50		......
	72	Feb. 3		5⅛		1	15	9	......	....	13.00		......
	73	Feb. 3		5⅛		1	15	9	......	....	12.75		......
	74	Feb. 3		5⅛		1	15	9	......	....	13.00		......
	75	Feb. 3		5⅛		1	15	9	......	....	13.25		......
	76	Feb. 3		5⅛		1	15	12	......	....	12.75		......
	77	Feb. 3		5⅛		1	15	12	......	....	11.75		......
	78	Feb. 3		5⅛		1	15	12	......	....	12.50		......
	79	Feb. 3		5⅛		1	15	12	......	....	12.50		......
	80	Feb. 3		5⅛		1	15	12	......	....	12.50		......
	81	Feb. 3		5⅛		1	15	12	......	....	12.25		......
	82	Feb. 3		5⅛		1	15	12	......	.... ..	12.00		......
	83	Feb. 3		5⅛		1	15	12	......	....	12.25		......
	84	Feb. 3		5⅛		1	15	12	......	....	12.00		......
	85	Feb. 3		5⅛		1	15	12	......	....	12.75		......
	86	Feb. 3		5⅛		1	15	12	......	....	12.25		......

Sandy Hook, N. J., from January 21 *to February* 20, 1885—Continued.

Time of flight.	Range.	Deflection.	Special remarks about each fire, such as effect on piece, sound of projectile in flight, scattering of fragments, &c.
"	*Yards.*	*Yards.*	
8	2,346	16 left	Fired to sea for ranges. Height of axis of trunnion of gun above mean low-water mark, 15.1 feet. Axis of gun, 13.33 feet above sea-level.
7¾	2,345	14 left	
7¾	2,342	13 left	
8¼	2,361	14 left	
8	2,342	13 left	
7½	2,335	11 left	
7¾	2,327	11 left	
8	2,352	12 left	
7¾	2,267	10 left	
8	2,312	10½ left	
11	Lost.	Lost.	Axis of gun, 13.8 feet above sea-level.
11	2,982	11¾ left	
Lost.	2,989	12½ left	
11	2,989	12½ left	
11	2,985	14½ left	
11¼	2,996	13½ left	
11	3,002	13¾ left	
10¾	2,996	13½ left	
11	3,012	16¾ left	
11	2,998	15½ left	
11	2,998	15½ left	
14	3,592	13½ left	Axis of gun, 14.55 feet above sea-level.
Lost.	Lost.	Lost.	
14¼	3,589	17½ left	
13¾	3,596	9 left	
14	3,604	14 left	
14	3,614	14½ left	
13¾	3,569	12 left	
13¾	3,567	16¾ left	
14	3,626	14¾ left	
14	3,626	14¾ left	
14	3,569	12 left	

Record of firing with Hotchkiss 42-millimeter mountain gun No. 64,

	No. of fire.	Time.	Powder.		Projectile.			Elevation.	Instrumental velocity at 550 feet from gun.	Instrumental velocity at 100 feet from gun.	Recoil.	Wind, strength and direction.	Angle of jump.
			Kind.	Weight, ounces.	Kind.	Wt. Pounds.	Wt. Ounces.						
		1885.						°	*Feet.*	*Feet.*	*Feet.*		′
A. M.—Barometer, 29.575; thermometer, 37.4; humidity, 82.	87	Feb. 4	Du Pont's H. N. Density, 1.607; granulation, 22,930.	5½	Hotchkiss (with point fuze).	1	15	0	......	....	13.00	From rear and left 48°; 3 m. an hour.	19
	88	Feb. 4		5½		1	15	0	......	....	13.00		
	89	Feb. 4		5½		1	15	0	......	....	12.50		
P. M.—Barometer, 29.440; thermometer, 32; humidity, 85.	90	Feb. 4		5½		1	15	3	......	....	13.00	From rear and left 3°; 4 miles an hour.	23
	91	Feb. 4		5½		1	15	3	......	....	13.50		
	92	Feb. 4		5½		1	15	3	......	....	14.00		
	93	Feb. 4		5½		1	15	6	......	....	14.75		25
	94	Feb. 4		5½		1	15	6	......	....	15.00		
	95	Feb. 4		5½		1	15	6	......	....	15.00		
A. M.—Barometer, 30.110; thermometer, 21; humidity, 76.	96	Feb. 14		5½		1	15	12	......	....	Recoils not noted.	From rear and left 48°; 21 miles an hour.	22
	97	Feb. 14		5½		1	15	12	......	....			
	98	Feb. 14		5½		1	15	12	......	....			
	99	Feb. 14		5½		1	15	12	......	....			
	100	Feb. 14		5½		1	15	12	......	....			
	101	Feb. 14		5½		1	15	9	......	....			20
	102	Feb. 14		5½		1	15	9	....	....			
	103	Feb. 14		5½		1	15	9	......	....			
P. M.—Barometer, 29.969; thermometer, 19.9; humidity, 58.	104	Feb. 19		5½		1	15	0	......	....	13.00	From rear and right 43°; 20 miles an hour.	15
	105	Feb. 19		5½		1	15	0	......	....	13.50		
	106	Feb. 19		5½		1	15	0	......	....	13.50		
	107	Feb. 19		5½		1	15	3	......	....	14.00		22
	108	Feb. 19		5½		1	15	3	......	....	14.00		
A. M.—Barometer, 29.953; thermometer, 14.8; humidity, 67.	109	Feb. 20		5½		1	15	3	.....	....	13.50	From rear and left 3°; 24 miles an hour.	
	110	Feb. 20		5½		1	15	6	......	....	13.75		22
	111	Feb. 20		5½		1	15	6	......	....	13.75		
	112	Feb. 20		5½		1	15	6	......	....	13.75		
	113	Feb. 20		5½		1	15	9	......	....	13.50		19
	114	Feb. 20		5½		1	15	9	......	....	13.50		
	115	Feb. 20		5½		1	15	9	......	....	13.50		
	116	Feb. 20		5½		1	15	12	......	....	13.00		17
	117	Feb. 20		5½		1	15	12	... ..	....	12.50		
	118	Feb. 20		5½		1	15	12	......	....	12.50		

Sandy Hook, N. J., from January 21 to February 20, 1885—Continued.

	Special remarks about each fire, such as effect on piece, sound of projectile in flight, scattering of fragments, &c.
Fired at target, distant 100 feet from gun, to determine angle of jump.	From rounds 1-95 gun was fired from plank walk.
	Gun fired from plank walk, rounds 104-118.

PLATE I.

Target Record

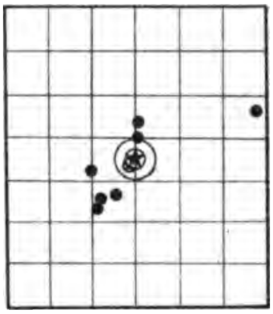
of

Hotchkiss 42 m/m (Cal. 1.65) Mountain Gun No. 64

at Sandy Hook N.J. January 30 1885

Target 620 feet from gun.

Number of Shots fired	7
Direct hits	7
Ricochet hits	0
Misses	0



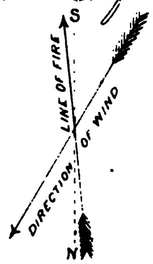
✪ POINT AIMED AT.

⊛ CENTRE OF IMPACT.

Mean vertical deviation from centre of impact 0.77

Mean horizontal deviation from centre of impact 0.83

Mean deviation from centre of impact 1.13



Target 6 x 7 feet

Wind 3 miles an hour

Appendix 13—1885.

H Ex1 pt2 v3 49 1

PLATE II.

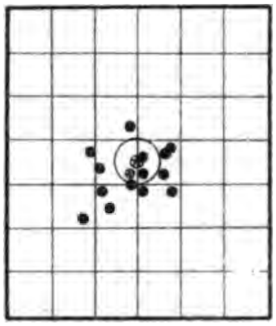
Target Record

Hotchkiss 42 $^{m}/_{m}$ (Cal. 1".65) Mountain Gun No. 64

at Sandy Hook, N. J. January 23, 1885.

Target 620 feet from gun.

Number of shots fired	15
Direct hits	14
Ricochet hits	0
Misses	1

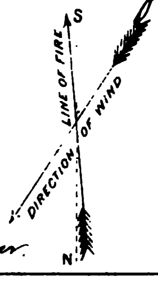


⊛ POINT AIMED AT.

⊗ CENTRE OF IMPACT.

Mean vertical deviation from centre of impact	0.48
Mean horizontal deviation from centre of impact	0.63
Mean deviation from centre of impact	0.80

Target 6 × 7 feet.



Wind 4 miles an hour.

Appendix 13—1885.

APPENDIX 14.

TRIAL OF BANDED 8-INCH PROJECTILES (EXPERIMENTAL). BY THE ORDNANCE BOARD.

(7 plates.)

The Chief of Ordnance in the first indorsement, dated December 8, 1884, on Ordnance Office file 6555 of 1884, directed the Ordnance Board to fire certain 8-inch projectiles sent from Watertown Arsenal.

The projectiles (see Plate) were in six lots of five each. The lots were marked No. 1, No. 1 modified, No. 2, No. 3, No. 4, and No. 5. The body of the shot was the same in all, but the arrangement of the bands was different in each lot. All the bands were beveled front and rear. No. 1, No. 1 modified, 2, and 3 had single bands with exterior surfaces which, independent of the front and rear bevel, were one inch wide.

The band of No. 1 commenced with a cylindrical surface 0.4 inch wide, 8.14 inches in diameter, and ended in a conic frustum 0.6 inch wide, having a minimum diameter of 8.08 inches.

The band of No. 1 modified had a fillet 0.15 inch wide, 8.15 inches in diameter, then a cylindrical surface 0.85 inch wide, 8.08 inches in diameter.

In No. 2 the surface of the band was a conic frustum with maximum and minimum diameters of 8.15 inches and 8.08 inches.

No. 3 had a cylindrical band 1 inch wide, 8.14 inches in diameter.

No. 4 had two narrow cylindrical bands 0.32 inch wide, 8.14 inches in diameter.

No. 5 had two broader cylindrical bands 0.5 inch wide, 8.14 inches in diameter.

The bands were generally inserted in under-cut grooves 0.15 inch deep, but in one or more projectiles of each lot the grooves were 0.10 inch deep.

The trial of these projectiles began April 1, 1885. One of each lot, with a shallow groove, was fired into the sand butt. The position of the band on the projectile was marked before firing, so that if during firing any slipping should take place it could be observed. The projectiles were recovered from the butt, and it was apparent that the bands had not changed their position. The remainder of the shot were fired for accuracy, and the results are given in the inclosed target record. The results with No. 1 and No. 2 are invalidated to some extent by the very variable velocities and pressures given by the powder used. An examination showed that some of the powder had been damaged by long storage. Lots 3, 4, and 5 were fired with powder obtained by mixing the contents of seven barrels together, and the results, as shown by comparing the velocities and pressures, were more uniform. The principal influence of variations in velocity would be upon the mean vertical deviation fromthe center of impact, and, leaving this out of consideration, the record shows that the projectiles marked No. 4 and No. 5 were the best.

Of these two the mean horizontal and mean absolute deviations were less for No. 5 than for No. 4. On the other hand, with the same angle of elevation, 2° 25′, the center of impact was about 7 feet below the point aimed at with No. 5, while it was 6 inches below for No. 4; and although the bands of No. 5 were broader, and more resistance might have been expected, the mean pressures and velocities were:

For No. 5, mean velocity 1,509 feet, mean pressure 30,537 pounds.

For No. 4, mean velocity 1,525 feet, mean pressure 31,600 pounds.

This accounts for the fact that the center of impact was higher for No. 4 than for No. 5.

As, however, the mean horizontal and mean absolute deviation were less for No. 5 than for No. 4 the Board would state that, from the limited experiments carried on so far, it has come to *the conclusion* that the projectile marked No. 5 is superior to the others, and that the shallow groove prevents the band from slipping as well as the deeper one.

T. G. BAYLOR,
Colonel of Ordnance, President of the Board.
GEO. W. McKEE,
Major of Ordnance.
CHARLES SHALER,
Captain of Ordnance.

Record of firing with 8-inch breech-loading chambered rifle No. 1,

	No. of fire.	Time.	Powder.		Projectile.		Elevation.	Pressure, per square inch of bore. Crusher.	Instrumental velocity 108¼ feet from muzzle.	Recoil.	Wind, strength and direction.
			Kind.	Weight.	Kind.	Weight.					
				Lbs		Lbs	° '	Lbs.	Feet.	Feet.	
P. M.—Barometer, 30.189; thermometer, 57.9; humidity, 42.	13	Apr. 1	E. V. F...	50	No. 1.....	180	35	36, 000	1, 593	4. 67	From rear and right, 87°, 14 miles an hour.
	14	Apr. 1	Du Pont's hexagonal E. V. M. Density, 1.750; Granulation, 72.	50	No. 1, modified.	180	35	32, 050	1, 523	4. 33	
A. M.—Barometer, 30.379: thermometer, 38.1; humidity, 70.	15	Apr. 2		50	No. 2......	180	35	30, 700	Lost.	4. 16	From front and left, 87°, 20 miles an hour.
	16	Apr. 2		50	No. 3......	181	35	31, 050	1, 523	4. 25	
	17	Apr. 2		50	No. 4......	181	35	32, 000	1, 533	4. 27	
	18	Apr. 2		50	No. 5......	183	35	34, 800	1, 534	4. 16	
A. M.—Barometer, 29.909; thermometer, 53.2; humidity, 70.	19	Apr. 3		50	No. 1......	181	2 30	32, 750	1, 538	4. 67	From front, miles an hour. 18
	21	Apr. 3		50	No. 1......	180	2 25	32, 200	1, 537	4. 42	21
	22	Apr. 3		50	No. 1......	180	3 25	28, 800	1, 490	4. 25	16
	23	Apr. 3		50	No. 1......	180	2 25	27, 950	1, 480	4. 25	22
	20	Apr. 3		50	No. 1, modified.	181	2 25	33, 500	1, 534	4. 58	18
	24	Apr. 3		50	No. 1, modified.	181	2 25	30, 125	1, 503	4. 33	20
P. M.—Barometer, 29.784; thermometer, 64.8; humidity, 64.	25	Apr. 3		50	No. 1, modified.	181	2 25	32, 450	1, 514	4. 33	From front and right, 3°, miles an hour. 25
	26	Apr. 3		50	No. 1, modified.	181	2 25	31, 000	1, 513	4. 25	27
	27	Apr. 3		50	No. 2......	181	2 25	32, 100	1, 517	4. 25	28
	28	Apr. 3		50	No. 2......	180	2 25	22, 300	1, 313	3. 75	30
	29	Apr. 3		50	No. 2......	181	2 25	20, 900	1, 271	3. 62	30

at Sandy Hook, N. J., from April 1 *to April* 7, 1885.

Distance from center of target, in feet.				Distance from center of impact, in feet.				Special remarks about each fire, such as effect on piece, sound of projectile in flight, scattering of fragments, &c.
Vertical.		Horizontal.		Vertical.		Horizontal.		
Above.	Below.	Right.	Left.	Above.	Below.	Right.	Left.	
Fired into sand butt.								
200 yards beyond.								
2.00	....	3.00	....	6.00	....	3.50	....	
....	10.00	....	4.00	....	6.00	....	3.50	
8 feet short.								
2.00	10.00	3.00	4.00	6.00	6.00	3.50	3.50	Mean vertical deviation from center of impact, 6′. Mean horizontal deviation from center of impact, 3′.50. Mean deviation from center of impact, 6′.95.
8.00+2=4.00		1.00+2=0.50		12.00+2=6.00		7.00+2=3.50		
....	0.50	....	3.00	....	0.12	....	2.00	Fired at mile target; target 20′ × 40′, made of 1″ spruce boards.
....	6.52	8.50	....	....	6.14	9.50	....	
1.00	....	....	....	1.38	....	1.00	....	
4.50	....	....	9.50	4.88	....	....	8.50	
5.50	7.02	8.50	12.50	6.26	6.26	10.50	10.50	Mean vertical deviation from center of impact, 3′.13. Mean horizontal deviation from center of impact, 4′.25. Mean deviation from center of impact, 5′.28.
1.52+4=0.38		4.00+4=1.00		12.52+4=3.13		21.00+4=5.25		
0.68	....	....	13.00	4.12	....	....	5.67	
....	14.00	....	6.00	....	10.56	1.33	....	
400 yards short.								

Record of firing with 8-inch breech-loading chambered rifle No. 1, at

	No. of fire.	Time.	Powder.		Projectile.		Elevation.	Pressure per square inch of bore. Crusher.	Instrumental velocity 108¼ feet from muzzle.	Recoil.	Wind, strength and direction.
			Kind.	Weight.	Kind.	Weight.					
				Lbs		*Lbs*	° ′	*Lbs.*	*Feet.*	*Feet.*	
P. M.—Barometer, 30.256; thermometer, 49.5; humidity, 69.	30	Apr. 7	Du Pont's hexagonal E. V. M. Density, 1.750; granulation, 72.	50	No. 2......	180	2 25	31, 850	1, 508	4. 42	From front, 16 miles an hour.
	31	Apr. 7		50	No. 3......	185	2 25	31, 600	1, 507	4. 42	20
	32	Apr. 7		50	No. 3......	183	2 25	31, 900	1, 510	4. 16	18
	33	Apr. 7		50	No. 3......	186	2 30	31, 000	1, 494	4. 00	20
	34	Apr. 7		50	No. 3	181	2 30	30, 300	1, 501	4. 00	19
	35	Apr. 7		50	No. 4.....	180	2 25	31, 925	1, 527	4. 16	19
	36	Apr. 7		50	No. 4.....	181	2 25	31, 900	1, 525	4. 08	16
	37	Apr. 7		50	No. 4......	181	2 25	31, 225	1, 528	4. 25	15
	38	Apr. 7		50	No. 4......	181	2 25	31, 350	1, 517	4. 08	14
	39	Apr. 7		50	No. 5......	182	2 25	30, 450	1, 507	4. 00	19
	40	Apr. 7		50	No. 5......	183	2 25	31, 550	1, 510	4. 08	20
	41	Apr. 7		50	No. 5......	185	2 25	29, 500	1, 510	4. 08	18
	42	Apr. 7		50	No. 5......	184	2 25	30, 650	1, 509	4. 08	19

Sandy Hook, N. J., from April 1 *to April* 7, 1885—Continued.

Distance from center of target, in feet.				Distance from center of impact, in feet.				Special remarks about each fire, such as effect on piece, sound of projectile in flight, scattering of fragments, &c.
Vertical.		Horizontal.		Vertical.		Horizontal.		
Above.	Below.	Right.	Left.	Above.	Below.	Right.	Left.	
3.00	....	....	2.99	6.44	....	4.34	....	Fired at mile target; target 20′ × 40′, made of 1″ spruce boards. From the 30th round charges were made up from 7 barrels, carefully mixed.
3.68	14.00	....	21.99	10.56	10.56	5.67	5.67	
10.32÷3=3.44		21.99÷3=7.33		21.12÷3=7.04		11.34÷3=3.78		Mean vertical deviation from center of impact, 7′.04. Mean horizontal deviation from center of impact, 3′.78. Mean deviation from center of impact, 7′.99.
....	10.00	....	3.00	....	1.75	....	4.37	
....	11.00	6.00	....	....	2.75	4.63	....	
....	9.00	1.48	....	....	0.75	0.11	....	
....	3.00	1.00	....	5.25	....	....	0.37	
....	33.00	8.48	3.00	5.25	5.25	4.74	4.74	
33.00÷4=8.25		5.48÷4=1.37		10.50÷4=2.62		9.48÷4=2.37		Mean vertical deviation from center of impact, 2′.62. Mean horizontal deviation from center of impact, 2′.37. Mean deviation from center of impact, 3′.53.
2.50	....	....	5.00	2.79	....	....	2.75	
0.34	....	....	1.00	0.63	....	1.25	....	
....	0.50	....	3.00	....	0.21	....	0.75	
....	3.50	....	....	....	3.21	2.25	....	
2.84	4.00	....	9.00	3.42	3.42	3.50	3.50	
1.16÷4=0.29		9.00÷4=2.25		6.84÷4=1.71		7.00÷4=1.75		Mean vertical deviation from center of impact, 1′.71. Mean horizontal deviation from center of impact, 1′.75. Mean deviation from center of impact, 2′.45.
....	10.00	2.50	....	....	2.75	1.46	....	
....	7.00	0.50	....	0.25	....	....	0.54	
....	9.00	0.66	....	....	1.75	....	0.38	
....	3.00	0.50	....	4.25	....	....	0.54	
....	29.00	4.16	....	4.50	4.50	1.46	1.46	
29.00÷4=7.25		4.16÷4=1.04		9.00÷4=2.25		2.92÷4=0.73		Mean vertical deviation from center of impact, 2′.25. Mean horizontal deviation from center of impact, 0′.73. Mean deviation from center of impact, 2′.35.

PLATE II.

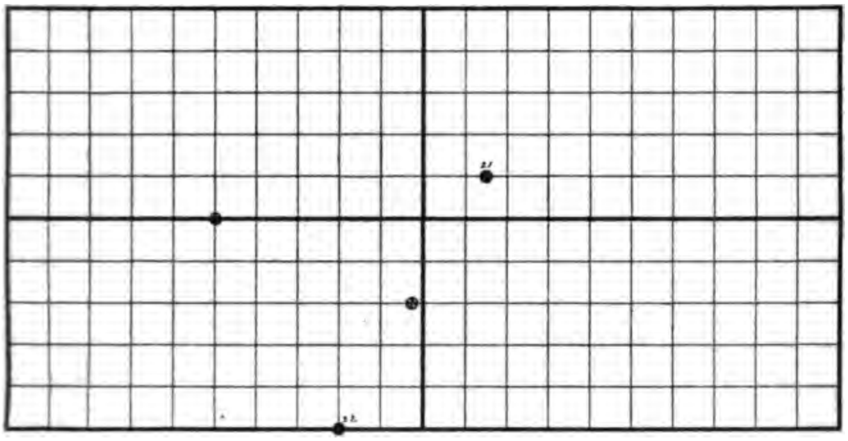
TARGET RECORD of 8-inch breech loading chambered rifle No 1

April 3 1885 AT SANDY HOOK, N. J.

No 1 Band

Target One Mile *from Gun.*

Number of shots fired, 4 . *Direct hits,* 2 . *Ricochet hits,* 0 . *Misses,* 2



● *Center of impact*

● *Point aimed at.*

Target 20′ × 40′

Mean vertical deviation from center of impact, 6.00.

Mean horizontal deviation from center of impact, 2.50.

Mean deviation from center of impact, 6.50.

Wind Round 19 10
20-21
21-16
22-22 *miles per hour.*

H Exl pt2 v3 40 1

PLATE III.

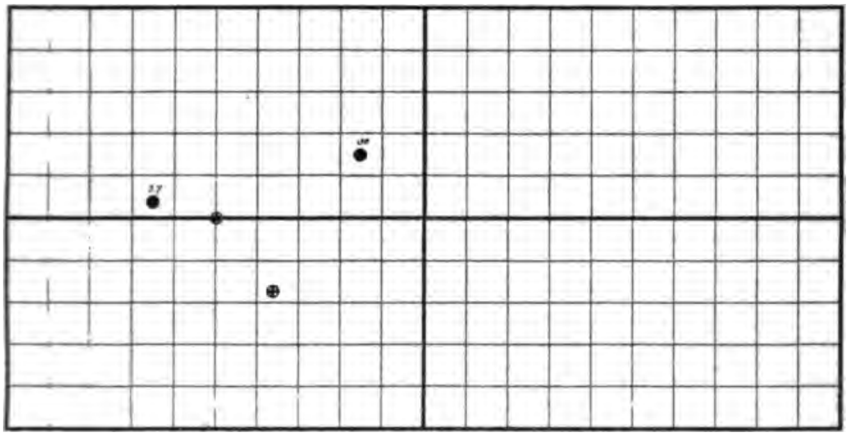
TARGET RECORD of 8 inch Breech Loading Chambered Rifle No 1

April 3rd 1885 AT SANDY HOOK. N. J.

No 2 Band.

Target One Mile *from Gun.*

Number of shots fired, 4 *Direct hits,* 3 *Ricochet hits,* 0 *Misses,* 1.



● *Center of impact.*

⊕ *Point aimed at.*

Target 20′ × 40′

Mean vertical deviation from center of impact, 7.08.

Mean horizontal deviation from center of impact, 3.70.

Mean deviation from center of impact, 7.97.

Wind Round 27. 28 / 29. 30 / 29. 30 / 30. 16 } *miles per hour.*

PLATE IV.

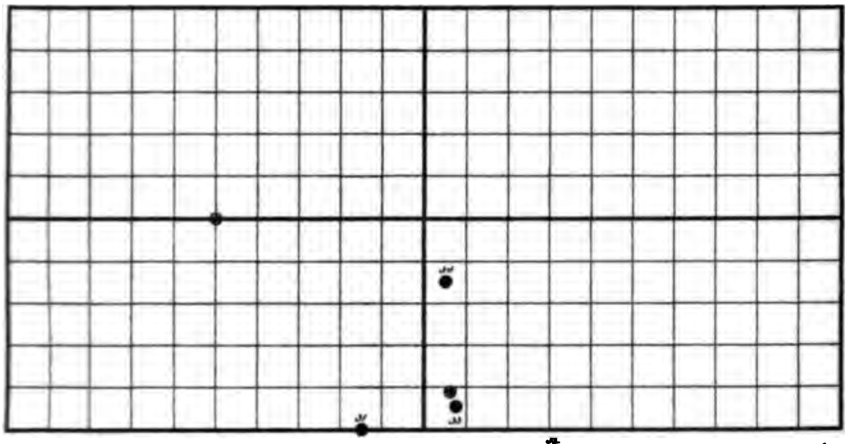
TARGET RECORD of [illegible] No. 1

April 7 1885 AT SANDY HOOK. N. J.

No. 3 Bend.

Target One Mile *from Gun.*

Number of shots fired, 4 *Direct hits,* 4 *Ricochet hits,* 0 *Misses,* 0



● *Center of impact.*

● *Point aimed at.*

Target 20' × 40'.

Mean vertical deviation from center of impact, 2.62

Mean horizontal deviation from center of impact, 2.37

Mean deviation from center of impact, 3.53

Wind Round 1st. 20 / 2d. 18 / 3d. 20 / 4th. 19 *miles per hour.*

Appendix 14—1885.

H Ex1 pt2 v3 491

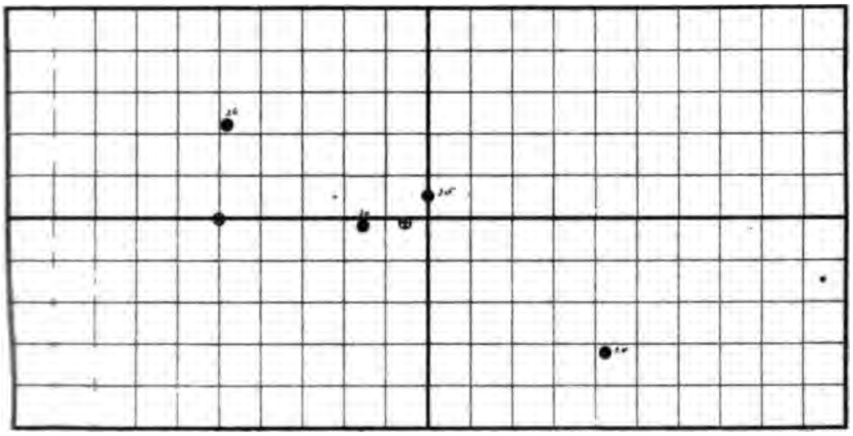
TARGET RECORD of 8 inch breech loading Chambered rifle No 1

No 1 Band - modified.

April 3 1885 AT SANDY HOOK. N. J.

Target One Mile *from Gun.*

Number of shots fired, 4. *Direct hits,* 4 *Ricochet hits,* 0 *Misses,* 0



● *Center of impact.*

● *Point aimed at.*

Target 20′ × 40′.

Mean vertical deviation from center of impact, 3.10

Mean horizontal deviation from center of impact, 4.25

Mean deviation from center of impact, 5.28

Wind Round 20 - 19 miles per hour.
24 - 20
25 - 25
26 - 17

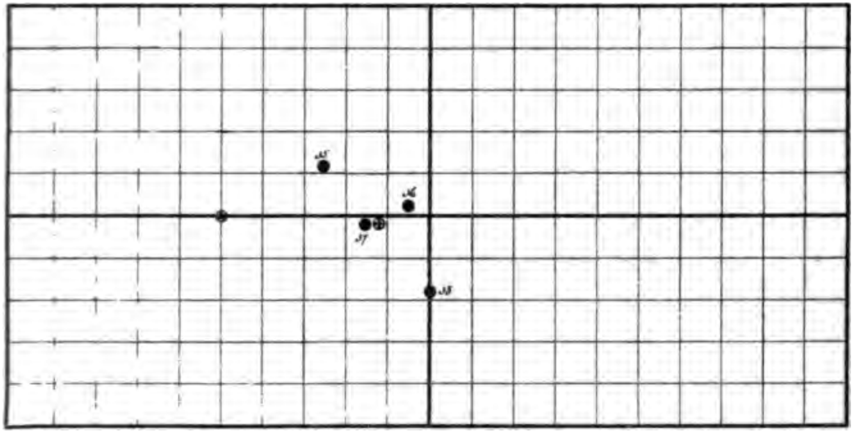
TARGET RECORD of 8 inch breech loading Chambered rifle No 1

No 4, Band

April 7, 1885 AT SANDY HOOK. N. J.

Target One mile *from Gun.*

Number of shots fired, 4 . *Direct hits,* 4 . *Ricochet hits,* 0 . *Misses,* 0 .



⊕ *Center of impact.*

✱ *Point aimed at*

Target 20' × 40'

Mean vertical deviation from center of impact, 1.71.

Mean horizontal deviation from center of impact, 1.75

Mean deviation from center of impact, 2.45

H Ex1 pt2 v3 49 1

Wind Round 35 2 / 36 2 / 37 16 / 38 10 } *miles per hour.*

Appendix 14—1886.

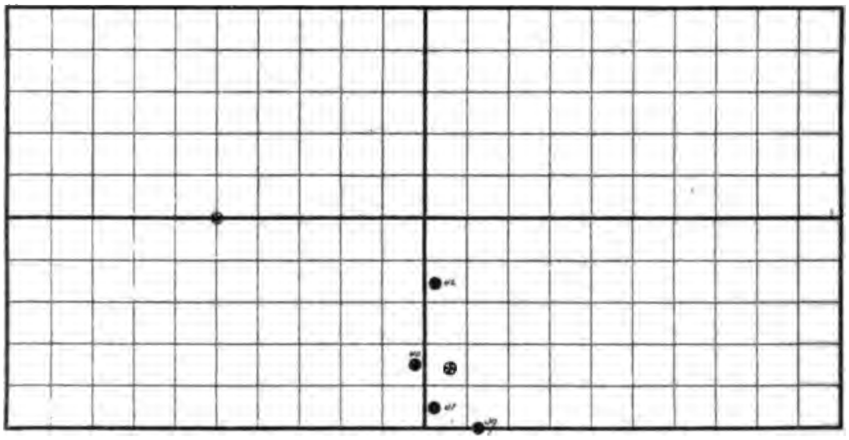
TARGET RECORD of 8 inch Breech loading Converted rifle No 1

April 7. 1885 AT SANDY HOOK. N. J.

No. 5 Band

Target One Mile ..... *from Gun.*

Number of shots fired, 4 ... *Direct hits,* 4 .... *Ricochet hits,* ...... 0 ..... *Misses,* ..... 0 ....



● *Center of impact.*

⊕ *Point aimed at.*

Target 20' × 40'

Mean vertical deviation from center of impact, ... 2.25

Mean horizontal deviation from center of impact, ... 0.78

Mean deviation from center of impact, ... 2.35

Wind Round 35 18 / 36 18 / 37 15 / 38 14 ... *miles per hour.*

APPENDIX 15.

C. P. WINSLOW'S NITRO-GLYCERINE SHELLS. BY THE ORDNANCE BOARD.

(1 plate.)

The Chief of Ordnance, in a letter dated January 8, 1885, stated that Mr. C. P. Winslow, the inventor of a nitro-glycerine shell, would call upon the Board and explain the device. The letter further authorized the Board, if it deemed the plan feasible, to order a few shells at the expense of the Department. After examination it was concluded that the invention possessed sufficient merit to warrant a trial, and Mr. Winslow was requested to have four shells made.

The projectile (see plate) is formed, like a Butler shell, with an appendage resembling a cascabel. The neck of the appendage, to which a wrench is fitted, is hexagonal. The part corresponding to the knob is a cylinder terminating in a spherical segment. The projectile is divided into two sections. The anterior part is a cylinder with an ogival head and contains a cavity in which the ingredients to produce an explosive compound are contained. This section terminates at the rear end in a screwed tenon, by means of which it is fastened to the rear section. The rear section is provided with a cavity intended to receive a cast-iron plunger and a charge of rifle-powder. Near the base of the projectile is a circumferential groove in which time-fuze composition is driven. This groove is connected with the rifle-powder in rear of the plunger. An axial chamber is bored in the plunger and contains a small charge of rifle-powder. The rear of this chamber is closed by a screw-plug containing a vent filled with slow-burning composition.

The materials used for producing an explosive compound are glycerine and concentrated nitric and sulphuric acids. One-half quart of sulphuric acid and three quarts of glycerine were mixed in one vessel and one and one-half quarts of sulphuric and two quarts of nitric acid were mixed in another. A portion of the first mixture was placed in a large glass jar, while a small jar placed within the first was filled with a portion of the second mixture. The liquid contents of the inner jar, and of the outer jar when the inner one is inserted, are equal in quantity, hence the proportions of the liquids are, sulphuric acid, 2; nitric acid, 2, and glycerine, 3. The usual proportions, when nitro-glycerine is manufactured by the ordinary processes, are about as follows: Sulphuric acid, 6; nitric acid, 3; glycerine, 1.

The jars are fastened together by screw-caps and are placed within a tin cylinder, open at both ends, which fits the shell cavity. Stout cross-bars traverse the open ends of the cylinder and the exterior glass vessel is fastened to the bars by strong bands, which, aided by rubber straps, are designed to prevent the rupture of the jars when the piece is fired. This rupture is intended to be effected in the following manner: The time-fuze is cut at any point, and when the projectile has traversed a certain portion of its trajectory the charge of rifle-powder in rear of the plunger is fired and the plunger is forced violently forward. This breaks the bottles and, in connection with the rotation of the shell and the broken fragments, causes an intimate mixture of the glycerine and the acids with formation of an explosive compound. When the projectile strikes a resisting object the shock of impact should cause the explosion of the compound thus formed, or, if this does not occur, then the charge contained in the axial chamber of the plunger will bring about the explosion.

The trial commenced April 23, 1885, when a shell was fired over the water from an 8-inch muzzle-loading rifle with 35 pounds of powder. It could not be ascertained whether or not an explosion had taken place, for from the fragments that struck near the gun it appeared probable that the projectile had been broken up by the shock of discharge. A second round was fired over land with 30 pounds of powder, the fuze being set at five seconds. The shell burst in the air in two and one-half seconds, and from the peculiar appearance of the smoke the rupture was regarded as due to the explosion of a substitution compound. In the third round fired with a 30-pound charge over the water no explosion took place. The fourth projectile was exploded by means of an electric primer in an inclosure. The shell broke at the screw-thread into two pieces, the head being thrown some 25 feet out of the inclosure. The bottom was forced against the side of the inclosure.

In conclusion, the Board would report that the acids can be safely transported to any point. The mixture can be effected without danger, and a shell arranged to contain them may be fired from a gun without injury to it. With the mixture used an explosive compound is probably formed, although the proportions of the ingredients were not such as to give the best results. If they had been, and if the greatest possible amount of nitro-glycerine producible by the ingredients which the shell cavity could contain were formed, it is not thought that the effect would be equal to that resulting with an ordinary bursting charge of gunpowder.

The Board would therefore recommend that no further trials be carried on with this device or with devices closely resembling it in principle.

T. G. BAYLOR,
Colonel of Ordnance, President of the Board.
GEO. W. McKEE,
Major of Ordnance.
CHARLES SHALER,
Captain of Ordnance.

Record of firing with 8-inch muzzle-loading rifle, No. 7 (Breech

	Number of fire.	Time.	Powder.		Projectile.			Elevation.	Wind, strength and direction.
			Kind.	Wgt. Pounds.	Kind.	Weight. Pounds.	Weight. Ounces.		
		1885.						°	
P. M.—Barometer, 30.172; thermometer, 69.2; humidity, 46.	429	April 23	Du Pont's Hexagonal E. V. M. Density, 1.750. Granulation, 72.	35	Shell empty	166	......	......	From front and right 10°, 25 miles an hour.
					Glass bottle and tin case empty.	7	1½	5	
					Weight of nitric and sulphuric acids and glycerine.	3	6½	......	
					Total	176	8	......	
	430	April 23		30	Shell empty ...	166	......	......	From front and left 4°, 25 miles an hour.
					Glass bottle and tin case empty.	7	1½	5	
					Weight of acids and glycerine.	3	14½	......	
					Total........	177	......	.....	
	431	April 23		30	Shell empty	166	......	......	From front and right 10°, 25 miles an hour.
					Glass bottle and tin case empty.	7	1½	7½	
					Weight of nitric and sulphuric acids and glycerine.	3	6½	......	
					Total........	176	8	......	

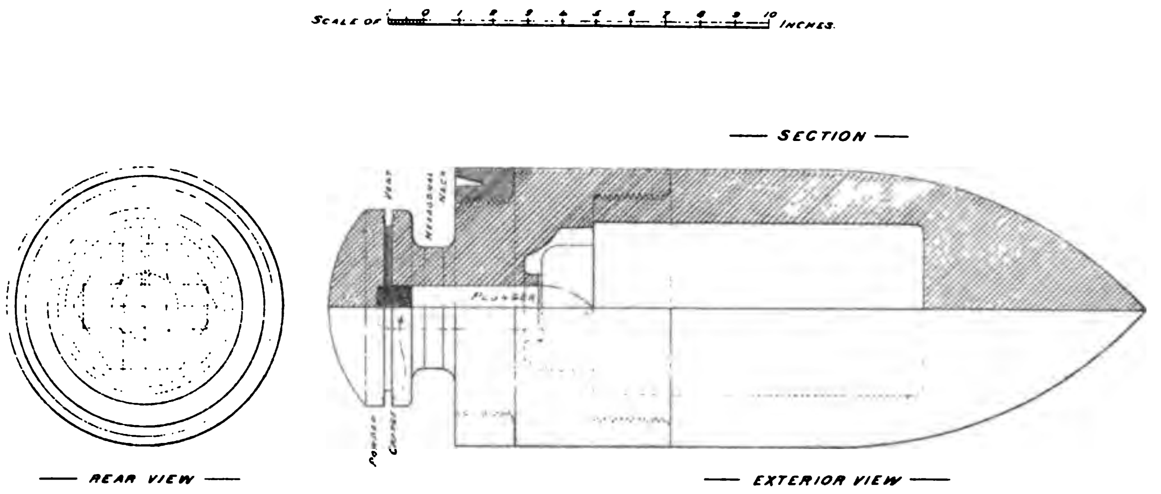
April 24..

insertion), at Sandy Hook, N. J., from April 23 to April 23, 1885.

			Special remarks about each fire, such as effect on piece, sound of projectile in flight, scattering of fragments, &c.
Fired to test method of forming and using nitro-glycerine according to plan furnished by Mr. Winslow.	**Fired over water. Fuze set at 3½ seconds.**	One and one-half quarts of sulphuric acid and two quarts of nitric acid and one pint of sulphuric acid and three quarts of glycerine were mixed in porcelain dishes and allowed to cool. Two arrangements of the bottles were used. In round 430 the bottles abutted against each other end to end, and in all other rounds the mixture of acids was in a bottle inclosed in a larger bottle containing the glycerine, about equal parts of the two mixtures being used in all cases.	Many small fragments struck water short distance in front of gun, and two large fragments about one mile away. Fourteen drachms powder in rear of plunger in shell. Six drachms powder in plunger
	Fired down beach. Fuze set at 5 seconds.		**Burst in 2½ seconds.**
	Fired over water. Fuze set at 11 seconds.		**Struck water without bursting in 7½ seconds.**
....	**A shell was prepared like those used in rounds 429 and 431. The slow match in base was removed and the shell exploded in an inclosure by means of an electric primer. The shell broke at the front screw-thread into two pieces, the head being thrown out of the inclosure about 25 feet, and the base against one side of the inclosure. The sides and bottom of the inclosure were smeared with the mixture.**		

WINSLOW'S NITRO-GLYCERINE SHELL

8 INCH



Ordnance Board U.S.A.
Governors Island May 19th 1885.

Appendix [illegible]

APPENDIX 16.

GARRICK'S MORTAR AND PROJECTILE FOR HIGH EXPLOSIVES.
BY THE ORDNANCE BOARD.

A letter from the Chief of Ordnance dated May 23, 1885, directed the Ordnance Board to try Mr. Garrick's new mortar and shell at as early a date as practicable, and report the result.

On May 26 Mr. Garrick delivered the letter in person and explained his device for firing gun-cotton, Atlas powder, dynamite, blasting-gelatine, nitro-glycerine, singly or combined, and requested that if there was any substance procurable which was a more violent explosive than those above mentioned, he might be supplied with it. He stated that he had made a very powerful explosive mixture composed of nitro-glycerine and charcoal dust, but that its power would be enhanced by substituting the powdered cinder from a smith's forge for the charcoal.

The piece was a cast-iron toy mortar with a cylindrical chamber, a bore 2½ inches long and 2 inches in diameter. With its bed it weighed 8.25 pounds. The teeth of a wheel fastened to the left trunnion intermeshed with those of two small pinions fastened to the mortar bed, one in front and one in rear of the trunnion bed. In the face of each pinion a slot was cut, into which the end of a strong lever could be inserted. Movement of the lever caused rotation of the pinion, and in accordance with the direction of this rotation the piece was elevated or depressed. A gripper fastened to the right side of the mortar bed could be closed by a lever, and when closed held the right trunnion firmly, preventing any change in the elevation of the mortar until the trunnion was released.

The projectile was composed of an outer shell with a hemispherical bottom, cylindrical sides, and a flanged mouth, the flange being wide enough to project slightly over the outside of the mortar when the shell was in place. A transom was bolted to the flange, and supported an inner spherical shell intended to contain the bursting charge. A tube screwed into the shell passed through the transom and was so arranged that a copper cartridge could be inserted and exploded by percussion or by a piece of quick-match. The inventor stated that the flange, by presenting a large surface for the action of the powder gases, would greatly increase the range, and that, furthermore, it would divert the inflamed gases and prevent the ignition of the fuze or the high explosive placed in the inner shell. The outer shell could be filled with water, which would diminish the shock of firing upon the bursting charge. The inventor further requested that cylindro-conoidal shells, charged with gun-cotton and his mixture of nitro-glycerine and charcoal dust, might be fired from a musket barrel provided by him; which request the Board acceded to.

The trial began May 28, 1885, and the results are shown in the inclosed firing record.

The conclusion of the Board is that any high explosive in the market could be fired with Mr. Garrick's small mortar and shell; that where such small firing and bursting charges are used they could be fired from his mortar with an ordinary shell; that Mr. Garrick's device is absurd, and to experiment with it any further would be ridiculous. The Board deems it its duty to remark that Mr. Garrick's ignorance of explosives and his carelessness in handling them are such that he should under no circumstances be permitted to experiment further at the proving ground, lest he may injure the Government employés or destroy Government property.

T. G. BAYLOR,
Colonel of Ordnance, President of the Board.
GEO. W. McKEE,
Major of Ordnance.
CHARLES SHALER,
Captain of Ordnance.

Record of firing with mortar and shot-gun barrel (Mr. Garrick's method of firing high explosives) at Sandy Hook, N. J., May 28, 1885.

MORTAR.

[Length bore, 2.25 inches; length powder chamber, 0.75 inch; diameter powder chamber, 0.75 inch; diameter bore, 2 inches; weight of mortar and carriage, 8.25 pounds.]

		No. of fire.	Time.	Powder. Kind.	Powder. Weight.	Projectile.	Projectile. Kind.	Projectile. Weight. Pounds.	Projectile. Weight. Ounces.	Wind, strength and direction.	Special remarks about each fire, such as effect on piece, sound of projectile in flight, scattering of fragments, &c.
Barometer, 30.103; thermometer, 65.3; humidity, 62.	a. m.	1	1885. May 28	K. G. Initial velocity, 1,300 feet.	*Oz.* $\frac{3}{16}$	Garrick shells.	Contained Atlas powder and gun-cotton in equal parts (no fuze).	1	$4\frac{1}{2}$	From front and left 20°.	Fired into air. Range 267 feet.
	a. m.	2	May 28		$\frac{5}{16}$		Contained Atlas powder and gun-cotton, and had fuze.	1	$4\frac{1}{2}$		Fired into air. Range about 300 feet. Shell did not explode.
	a. m.	3	May 28		$\frac{5}{16}$		Contained Atlas powder and gun-cotton, and had fuze.	1	$4\frac{1}{2}$		Fired into air. Range about 300 feet. Fuze exploded in the air.
	a. m.	4	May 28		$\frac{5}{16}$		Contained Atlas powder and gun-cotton, and had fuze.	1	$4\frac{1}{2}$	From front and left 42°; 28 miles an hour.	Fired into air. Shell burst in the air.
	p. m.	5	May 28		$\frac{5}{16}$		Contained Atlas powder and glycerine, and had fuze.	1	$10\frac{3}{16}$		Fired into air. Range about 320 feet. Shell did not explode.
							GUN BARREL. [Usual diminsions.]				
Barometer, 30.103; thermometer, 65.3; humidity, 62.	p. m.	1	May 28	K. G. Initial velocity, 1,300 feet.	*Grains.* 52		Contained gun-cotton (brass).	....	$2\frac{3}{16}$	From front and left 42°; 28 miles an hour.	Fired at target distant 40 feet. Struck target. Did not explode.
	p. m.	2	May 28		52		Contained gun-cotton (cast-iron).	....	$2\frac{1}{16}$		Fired at target distant 40 feet. Struck target. Did not explode.
	p. m.	3	May 28		70		Contained glycerine in charcoal (cast-iron).	....	$2\frac{3}{16}$		Fired at target distant 40 feet. Struck target. Did not explode.

APPENDIX 17.

TRIAL OF SHELLS CHARGED WITH EXPLOSIVE GELATINE. BY THE ORDNANCE BOARD.

(1 plate.)

In its progress report on explosive gelatine (Appendix 19, Report of the Chief of Ordnance, 1884) the Ordnance Board stated that the trials of the gelatine in 8-inch cast-iron screw shells "were sufficiently successful to warrant the Board in suggesting six steel shells to be made." The suggestion having been approved, the shells were made at the Midvale Steel Works, and afterward machined at Sandy Hook and the West Point Foundry. Three of them were cast, and three forged. The ultimate tenacity of the cast was 122,398 pounds, and of the forged 150,066 pounds per square inch, respectively. The interior cavity was the same for all, being a cylinder terminated ogivally (as shown in plate), it being believed that this shape would give greater strength and penetration to the shells. The shells opened at the rear, and were closed by a base-screw.

In order to test the working of the projectiles as regards flight and penetration, one forged shell was fired with a charge of 36 pounds of E. V. M. powder, this being the reduced charge for 304½ feet as compared with 40 pounds at 1,000 yards. The shell was filled with sea sand, and upon being fired failed to take the grooves; struck the iron target sidewise and broke up. It was then decided to fire another forged shell filled with sand, using 40 pounds of powder (E. V. M.). This shell struck the target, point on, penetrated 9¼ inches, and rebounded about 12 feet. It was distorted but slightly (being bulged out circumferentially near junction of cylider and ogival head), and, with slight turning, could be used again. On taking out the base-screw the contained sand was found to be triturated by the shock into a powder as impalpable as ordinary wheat flour. No powder-gas had entered.

The third forged shell was then loaded with five pounds of gelatine—all it could contain. It was fitted with a copper diaphragm, two plates at right angles, previously described. A small amount of cotton waste was placed in front and rear of the gelatine. The latter was packed in tightly.

The gelatine was from the same lot hitherto used at Sandy Hook, and had been on hand for 16 months. So far as could be observed it had undergone no change whatever. Two of the cartridges appeared to the touch slightly softer than the others, but it is believed they were as sound as the rest.

The base screw had its thread well covered with red lead paint before being securely screwed in with a lever, and there seems to be no possibility of any gas having entered the shell.

The 8-inch mutilated gun, previously used in these experiments, having been charged with 40 pounds E. V. M. powder and the gelatine shell, was fired and burst explosively with great violence.

Whether or not this gelatine had undergone any change since the previous trials with it is, of course, unknown to the Board; but even if such should prove to be the case, the want of uniformity in its action, as evinced by this explosion, warrants the Board in recommending no further trials with it under its present form. Possibly when camphorated by competent manufacturers this explosive may be made uniform in its action.

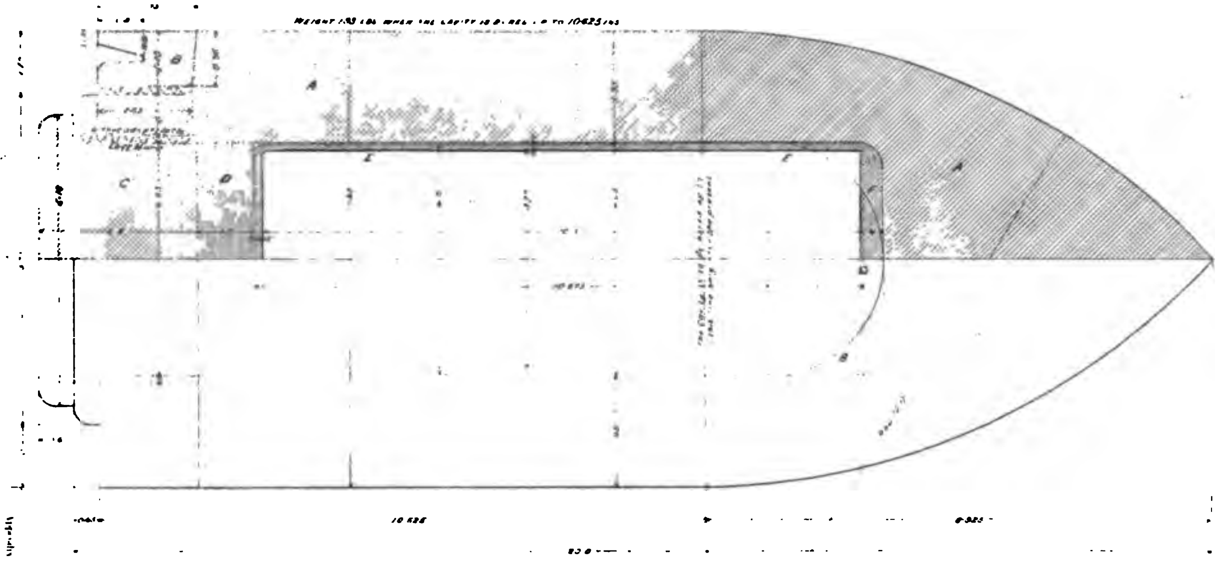
T. G. BAYLOR,
Colonel of Ordnance, President of the Board.
GEO. W. McKEE,
Major of Ordnance.
CHARLES SHALER,
Captain of Ordnance.

Record of firing with 8-inch muzzle-loading rifle, No. 7 (breech insertion), at Sandy Hook, N. J., from June 12 to June 17, 1885.

	Number of fire.	Time.	Powder.		Projectile.			Elevation.	Pressure, pounds per square inch of bore. New crusher.	Instrumental velocity, 100 feet from muzzle.	Wind, strength and direction.	Special remarks about each fire, such as effect on piece, sound of projectile in flight, scattering of fragments, &c.	
			Kind.	Weight.	Kind.	Weight.							
		1885.		*Lbs.*		*Lbs.*	*Oz.*	° ′		*Feet.*			
P. M. Barometer, 30.174; thermometer, 75.3; humidity, 43.	432	June 12	Du Pont's hexagonal E. V. M.; density, 1.750; granulation, 72.	36	(Forged) steel shell filled with sand. Steel shell empty.... Sand................ Total weight........ H. 6169.	 184 8 192	 8 8	5	27150	1280	From front and right 3°. 32 miles an hour.	Fired at iron casemate. Target distant 304¼ feet from gun.	Shell struck the target obliquely to left of bull's-eye aimed at, 18 inches above wooden bed; gouged the front plate, glancing off and breaking up. Maximum depth of penetration 4½ inches; length of elliptical cavity 18¾ inches, and width 9 inches. Effect of shot on target: Second bolt from bottom on first row to left of embrasure and second and third bolts from bottom on second row broken off at junction of front and rear plates. One bolt broken off at head, in left angle-iron.
	433	June 12		40	(Forged) steel shell filled with sand. Steel shell empty.... Sand................ Total weight........ H. 6170.	 183 8 191		3½	28400	1322			Shell struck bull's-eye aimed at normally and 16 inches above wooden bed; penetrated plate 9¼ inches, rebounded about 12 feet uninjured, except for slight deformation at the commencement of the cone. Cavity left in plate circular at surface of plate and 8¾ inches in diameter. Effect of shot on target: Third and fourth bolts from bottom row to left of embrasure and fourth bolt in second row broken off at junction of the front and rear plates. Two bolts broken off at their heads in left angle-iron. Front plate cracked through from second bolt hole first row to top of lower plate. Upper front plate moved over to left ¾ inches. Lower left back plate set back ¾ inches and split lengthwise.
P. M. Barometer, 29.984; thermometer, 71.1; humidity, 56.	434	June 17		40	(Forged) steel shell empty. Explosive gelatine.. Total weight........ Rubber buffer ...... H. 6117.	188 5 193 8	....	15	Lost ..	Lost ..	From rear and right, 43°. 8 miles an hour.	Fired at iron casemate. Target distant 305 feet from gun.	Shell divided into 4 longitudinal sections by sheet-copper diaphragms and gelatine packed in by hand, a small pad of cotton waste being placed at bottom and top. Gun burst, breaking into many small fragments from a plane passing through the front of the jacket to the muzzle collar.

8 INCH EXPLOSIVE GELATINE SHELL FOR M L RIFLE

FULL SIZE



AA-Steel B-Brass
C-Steel Plug
D-Elastic Cushion E-Paper Case
F-Paper Cover

Ordnance Board U.S.A.
Governors Island August 1884.

Appendix 17 1885

APPENDIX 18.

TRIAL OF THE GARDNER MACHINE GUNS, ONE, TWO, AND FIVE BARREL. BY THE ORDNANCE BOARD.

(4 plates.)

The Chief of Ordnance, in an indorsement dated December 8, 1884, on Ordnance Office file No. 6603 of 1884, directed the Board to test any of the guns of the Gardner Gun Company, of Cleveland, Ohio, which might be presented for trial.

The guns, three in number, were of the one, two, and five barrel patterns. As certain changes, hereinafter referred to, will have to be made in these guns before they can be considered as tested under service conditions, the Board submits, instead of the usual drawings and descriptions, an illustrated pamphlet issued by the Gardner Gun Company. This pamphlet was inclosure No. 1 of Ordnance Office file No. 6603 of 1884, is hereunto appended, and marked A.

The experiments began May 28, 1885, by the firing of the one-barrel gun, which was followed on the same day by that of the two and five barrel guns. Owing to the form of chamber it was necessary to use Winchester ammunition with the 405-grain bullet. The service ammunition carries the 500-grain bullet, which could not be fired from the gun as at first presented, and it was concluded, after correspondence with the Chief of Ordnance, to request the Gardner Gun Company to modify the two and five barrel guns so that they would receive the service ammunition. This request was acceded to; the guns were removed for alteration. It was not considered desirable to test the one-barrel gun, as in the opinion of the Board there does not at present exist any reason for its adoption in our service.

The guns, after modification, were received back, and a second series of trials commenced on July 24, 1885.

The following programme for the trial was adopted:

(1) Dismount the gun, separating it into its elementary parts, and assemble it. This to be done by an expert, and time noted.

(2) Fire deliberately 500 rounds into a sand butt, determining velocities and action of the gun.

(3) Rapidity by an expert, 500 rounds.

(4) Rapidity by a non-expert, 500 rounds.

Accuracy of gun and sights at various distances:

(5) 500 at 500 yards; size of target 11 by 26 feet.

(6) 500 at 1,000 yards; size of target 11 by 26 feet.

(7) 500 at 1 mile; size of target 11 by 52 feet.

This programme was not entirely carried out. The dismounting and assembling of the gun and the firing at 1-mile range were omitted.

It will be observed from the firing records of July 24 and 25 (which are inclosed) that the number of misfires with the service ammunition was very great, and that the cartridges which failed in the machine guns all exploded subsequently when tried in the Springfield rifle. The fault is not therefore attributable to the ammunition, and must be due either to weakness in the firing-spring or to the fact that the firing-pin is too short. In the opinion of the Board, the latter is most probably the cause.

The long feed-guide peculiar to the two-barrel gun required that the ordinary package containing twenty cartridges should be broken open, that the cartridges should be removed, and that they should be repacked into a feed-case. The violent vibration of the feed-guide, due to the firing of the gun, makes it very difficult for an inexperienced man to feed the cartridges from the case. These defects do not exist in the Pratt & Whitney gun, and it is thought that if practicable they should be remedied, as repacking the cartridges should be made as simple as possible, and a shorter guide would diminish the vibration. The guide is much shorter in the five-barrel gun, and of course with it the repacking of the cartridges is a necessity. These guns, furthermore, are mounted on tripods, a form of mounting that will only be used in permanent works. Other machine guns intended to re-enforce infantry fire heretofore tested at Sandy Hook have been furnished with suitable carriages, and they should be tested in connection with the gun.

Except for the failures to explode the cartridges, the mechanism of the guns worked very satisfactorily. The target record during deliberate firing was very good. The vibration of the stands during rapid firing caused the guns to change direction.

In conclusion, the Board would state that owing to defects in the locks, which can be remedied, to the length of the feed-guide, which can be modified, and to vibrations in the mounting, which should be changed for a more suitable one, it is not considered that these guns have as yet been given a fair service test; and, further, unless these changes are made, it is not considered for the interest of the Government to continue the tests any further.

The illustrated pamphlet above referred to, the complete firing records, and the plotted targets are inclosed herewith.

T. G. BAYLOR,
Colonel of Ordnance, President of the Board.
GEO. W. McKEE,
Major of Ordnance.
CHARLES SHALER,
Captain of Ordnance.

Record of firing with Gardner 1-barreled machine gun, caliber 0".45, at Sandy Hook, N. J., May 28, 1885.

		Number of fire.	Time. 1885. Month.	Time. 1885. Day.	Ammunition.	Wind, strength and direction.	Special remarks about each fire, such as effect on piece, sound of projectile in flight, scattering of fragments, &c.
A. M.		......	May ..	28	......	......	Firing-pin found to be too weak to fire cartridges; spring reset.
P. M.—Barometer, 30.105; thermometer, 61.9; humidity, 61.	Volley .	50	May ..	28	Winchester ammunition; 405-grain bullet.	From front and left 48°, 28 miles an hour.	Fired deliberately down beach; 9 failed once and 4 at a second attempt.
	Volley .	50	May ..	28			Fired deliberately down beach; 12 failed, but were fired at a second attempt.

Record of firing with Gardner 2-barreled machine gun, caliber

		Number of fire.	Time. 1885.		Ammunition.	Instrumental velocity, 50' from muzzle.	Wind, strength and direction.
			Month.	Day.			
						Feet.	
A. M. — Barometer, 30,040; thermometer, 73.8; humidity, 49.	Volley.	109	May..	28	Winchester ammunition; 405-grain bullet.	....	From rear and left, 48°, 20 miles an hour.
		2	May..	28	500-grain service cartridge.	....	
A.M.—Barometer, 30.023; thermometer, 80.6; humidity, 66.		1	July..	24	Frankford ammunition; 500-grain bullet.	Lost.	From front and right, 3°, 26 miles an hour.
		1	July..	24		Lost.	
		1	July..	24		Lost.	
		1	July..	24		Lost.	
		1	July..	24		Lost.	
		1	July..	24		Lost.	
		1	July..	24		1231	
		1	July..	24		1242	
P. M.—Barometer, 30.048; thermometer, 80.8; humidity, 68.		500	July..	24		....	
		490	July..	24		....	
		492	July..	24		....	
A.M.—Barometer, 29.921; thermometer, 80.8; humidity, 85.		3	July..	25		....	From front and right, 48°, 6 miles an hour.
		500	July..	25		....	
P.M.—Barometer, 29.848; thermometer, 86.3; humidity, 82.		3	July..	25		....	
		500	July..	25		....	

0".45, *at Sandy Hook, N. J., from May* 28 *to July* 25, 1885.

Special remarks about each fire, such as effect on piece, sound of projectile in flight, scattering of fragments, &c.

Locks were removed by representative of the company in 29 seconds; and with the assistance of Mr. Sinclair the remaining working parts were removed. The parts were then assembled by both of them in 9 minutes 40 seconds.

Fired deliberately into butt; 3 cartridges were ejected unexploded, two of which were fired at the second attempt; the third failing again, but being subsequently fired in a Springfield rifle. There was a marked vibration to firing stand during firing.

Too long to be fed from the feed-case; the cartridge was inserted by hand, fired, and ejected, but a second one jammed before firing, and was removed with difficulty.

The gun had been returned to Cleveland to be adapted to the service 500-grain ammunition. No feed-cases for this ammunition accompanied the gun on its return.

Fired deliberately into sand butt by representative of company; 11 failed to explode; 6 fired on second attempt.

Fired for rapidity into sand butt by representative of company; 50 failed to explode; 29 fired on second attempt. Time, 1 minute and 40¼ seconds.

Fired for rapidity into sand butt by representative of company. After 4 rounds had been fired a jam occurred, which necessitated the removal of the upper casing of gun and a cartridge case. Time, 1 minute 55¼ seconds; 47 failed to explode; 29 fired on second attempt.

Sighting shots at 500-yard target.

(Fired in lots of 50 each.) Fired at 500-yard target; 409 hits on target; 37 failed to explode, 13 of which fired on second attempt, and the remainder from a Springfield rifle.

Sighting shots at 1,000-yard target.

(Fired in lots of 50 each.) Fired at 1,000-yard target; 296 hits on target; 46 failed to explode, 19 of which fired on second attempt, and the remainder from a Springfield rifle.

Occasional, but slight, changes in aim occurred during deliberate firing, but in rapid firing the changes were very great.

The feed-cases not being adapted to the 500-grain bullet, the vibration of the gun was such during rapid firing that some of the cartridges were dropped in feeding, which at best was a difficult operation.

Record of firing with Gardner 5-barreled machine gun, caliber 0".45, at

	Number of fire.	Time. 1885. Month.	Time. 1885. Day.	Ammunition.	Instrumental velocity 50' from muzzle.	Wind, strength and direction.
					Feet.	
A. M.—Barometer, 30.040; thermometer, 73.8; humidity, 49. Volley.	100	May..	28	Winchester ammunition, 405-grain bullet.	....	From rear and left 48°, 20 miles an hour.
A.M.—Barometer, 30.023; thermometer, 80.6; humidity, 66.	1	July..	24	Frankford ammunition, 500-grain bullet.	Lost.	From front and right 3°, 26 miles an hour.
	1	July..	24		Lost.	
	1	July..	24		1267	
	1	July..	24		Lost.	
	1	July..	24		Lost.	
	1	July..	24		1279	
	1	July..	24		1289	
	250	July..	24		....	
	250	July..	24		....	
P. M.	38	July..	24		....	
	249	July..	24		....	
	250	July..	24		....	
	250	July..	24		....	
	250	July..	24		....	
A.M.—Barometer, 29.921; thermometer, 80.8; humidity, 85.	6	July..	25		....	From front and right 48°, 6 miles an hour.
	500	July..	25		....	
	6	July..	25		....	
	500	July..	25		....	

Sandy Hook, N. J., from May 28 *to July* 25, 1885.—Continued.

Special remarks about each fire, such as effect on piece, sound of projectile in flight, scattering of fragments, &c.	
Fired deliberately down beach without failures. There was a marked vibration to firing-stand during firing. This gun had been returned to Cleveland to be adapted to the service 500-grain ammunition. Only four feed-cases, containing 50 cartridges each, for this ammunition accompanied the gun on its return.	
Fired deliberately into sand butt; 6 failed to explode, 2 of which were fired on second attempt.	
Fired deliberately into sand butt; 18 failed to explode, 6 of which were fired on second attempt.	
Fired for rapidity into sand butt; 2 failed; stoppage occurred.	Total, 20; 8 failed on second attempt.
Fired for rapidity into sand butt by representative of company. Time, 31 seconds; 11 failed.	
Fired for rapidity into sand butt by representative of company. Time, 29 seconds; 7 failed.	
Fired for rapidity into sand butt by Mr. Sinclair. Time, 25½ seconds; 4 failed.	Total, 15; 7 failed on second attempt.
Fired for rapidity into sand butt by Mr. Sinclair. Time, 20½ seconds; 11 failed.	
Of all the misfires from the 2 and 5-barreled guns on July 24, 1885, only one failed when fired from a Springfield rifle.	
Sighting shots at 500-yard target.	
(Fired in lots of 50 each.) Fired at 500-yard target; 366 hits on target; 30 failed to explode, 19 of which were fired on second attempt, and the remainder from a Springfield rifle.	
Sighting shots at 1,000-yard target.	
(Fired in lots of 50 each.) Fired at 1,000-yard target; 248 hits on target; 33 failed to explode, 17 of which were fired on second attempt, and the remainder from Springfield rifle.	
Occasional but slight changes in aim occurred during deliberate firing, but in rapid firing the changes were very great.	

Target Record of Gardner Two Barrelled Machine Gun Calibre 0.45

At Sandy Hook N.J. July 23, 1885

Target 500 yards from gun

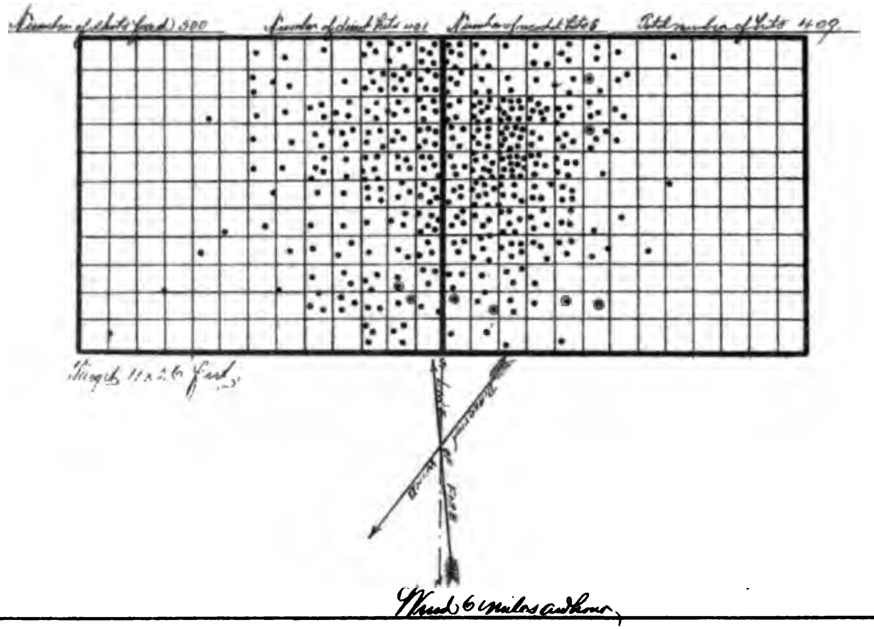


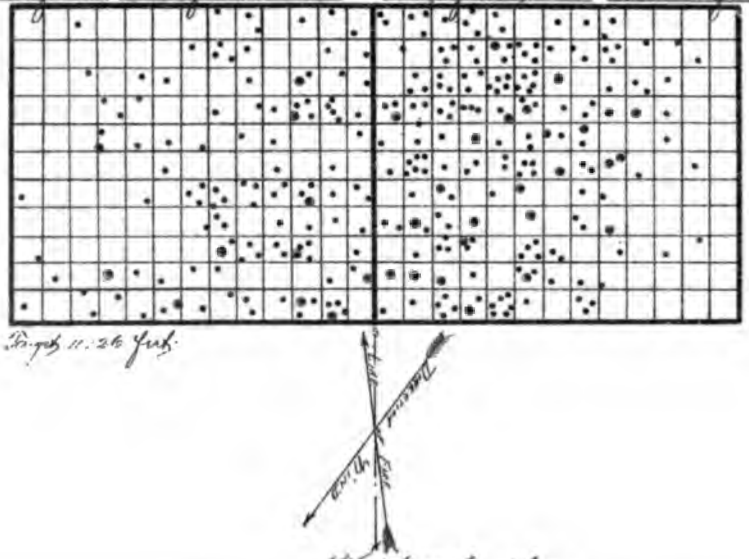
PLATE II.

Target Record of Gardner Two Barrelled Machine Gun Calibre 0".45

At Sandy Hook N.Y. July 25' 1885

Target 1000 yards from gun

Number of shots fired 300 Number of direct hits 260 Number of ricochet hits 36 Total number of hits 296



Target 11 : 26 feet.

Wind 6 miles an hour

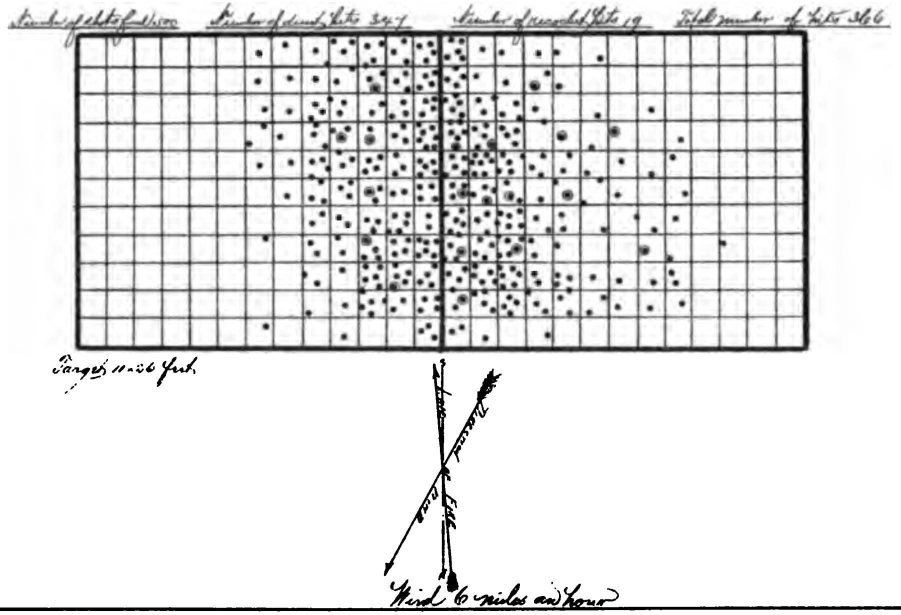
H Ex1 pt2 v3 491

Target Record of Gardner Five Barrelled Machine Guns Calibre .45.

(At Sandy Hook N.J.) July 25. 1885

Target 500 yards from gun

Number of shots fired 500 Number of direct hits 347 Number of ricochet hits 19 Total number of hits 366

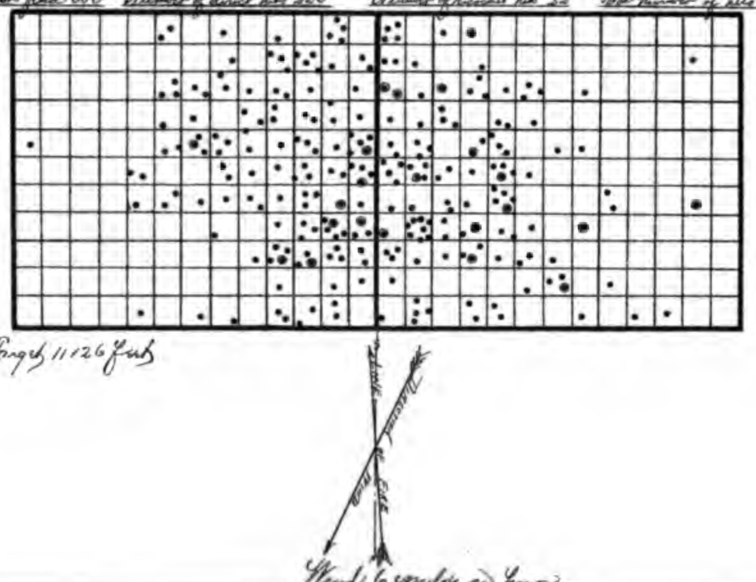


Target Record of Gardner Two Barrelled Machine Gun, Calibre 0.45

At Sandy Hook N.J. July 23 1885

Target 1000 yards from gun

Number of shots fired 500 Number of direct hits 226 Number of ricochet hits 22 Total number of hits 248



Target 11126 feet

Wind 6 miles an hour

H Ex1 pt2 v3 49 1

APPENDIX 19.

PRELIMINARY TRIAL OF THE 12-INCH MUZZLE-LOADING RIFLED MORTAR. BY THE ORDNANCE BOARD.

(1 plate.)

On December 3, 1884, the following communication, addressed by the Chief of Ordnance to the commanding officer, New York arsenal, was referred to the Ordnance Board:

> Captain Lyle reports having applied for transportation of the 12-inch muzzle-loading rifled mortar to Sandy Hook. When the mortar is received, it is requested that it may be mounted on its carriage and put in readiness for trial. Before being turned over to the Board for Testing Guns, you will please have it fired to the extent of the number of projectiles that have been furnished you. The object of these preliminary firings is to determine upon a suitable powder for the piece, to ascertain if the dimensions of the sabot are suitable, and if the thickness of the wall of the shell is sufficient, and incidentally to test the general working of the carriage. The maximum charge will be provisionally 52 pounds, and the shell will be ballasted by filling with sand or other material, to bring up the weight to 610 pounds.
>
> Under these conditions it is desired to obtain a muzzle velocity of 975 feet, without exceeding a pressure of 12 tons per square inch in the bore. To test the sabot fully, charges giving velocities of about 525 feet, or at least 675 feet, should be tried, using a quicker burning powder if necessary. It may be possible, and it is certainly very desirable, that the different velocities be all obtained with the same kind of powder, by using for the lower velocities a relatively larger charge than with the quicker powder. The limited number of rounds—15—now to be fired may, however, preclude the determination of this question at present.

* * * * * * *

The mortar which it is assumed has been described by the inspecting officer at South Boston Foundry was not received until March 12, 1885.

The projectiles were all supplied with the Eureka sabot (see Plate I). By changing the radius of the curved part of the posterior face of the sabot its sensitiveness may be varied.

The powder for the trials was the subject of experiment, as it was desirable to obtain such a mixture as would give the projectile a regular motion when fired with charges of about 25 pounds, and would when used in 50-pound charges not exceed the prescribed maximum pressures.

If no single powder could be obtained suitable for firing full and diminished charges, then two different kinds would have to be adopted.

The experiments were commenced on March 19, 1885, and are detailed in the accompanying firing record. The rounds from 1 to 14 were fired with various powders on hand at the proving ground, with a view to ascertaining what quality of powder would be desirable for the endurance test of the piece. As a result, it was determined that two kinds of hexagonal powder, M.W. (density 1.725, granulation 72) and M.V. (density 1.700, granulation 72), should be asked for. The latter was to be used for reduced charges only. The M.W. powder, the denser of the two, it was supposed might answer for reduced charges and maximum charges of 48 pounds. All the shots fired with 48-pound charges of M.W. powder gave good results. The mean pressure of three rounds was 30,660 pounds; the velocity at 90 feet from the muzzle was 970 feet.

All the shots fired with 25-pound charges of M.W. powder gave good results; but when a charge of 26 pounds [round 33] was fired the projectile tumbled. The indications, however, were that with a suitable sabot this powder might be used for full and reduced charges. All the shots fired with 25 pounds of M.V. powder gave good results.

The mean pressure of six rounds was 10,721 pounds; the velocity was 646 feet at about 90 feet from the muzzle. This indicated that, if a special powder was required for reduced charges, the M.V. type would be suitable.

By directions of the Chief of Ordnance, the mortar was, on July 9, 1885, turned over to the Testing Board convened in accordance with the act of Congress approved July 5, 1884.

T. G. BAYLOR,
Colonel of Ordnance, President of Board.
GEO. W. McKEE,
Major of Ordnance.
CHARLES SHALER,
Captain of Ordnance.

Record of firing with 12-*inch muzzle-loading rifled mortar*

	Number of fire.	Time.	Powder.		Projectile.		Elevation.	Pressure per square inch of bore. (Crusher.)	Instrumental velocity, 89' from muzzle.	Recoil.
			Kind.	Weight.	Kind.	Weight.				
		1885.		*Lbs*		*Lbs*			*Feet.*	*Feet.*
P. M.—Barometer, 29.726; thermometer, 26; humidity, 78.	1	Mar. 19	Du Pont's hexagonal K. I. Density, 1.650; granulation, .72.	25	Eureka shell.	572	—20′	Less than 18,000	690.5	5.87
A. M.—Barometer, 29.691; humidity, 66; thermometer, 14.8.	2	Mar. 20	Du Pont's sphero-hexagonal K. H. C. Density, 1.775; granulation, 123.	25	Eureka shell.	610	—15′	Less than 18,000	568	5.46
	3	Mar. 20	Du Pont's sphero-hexagonal K. B. A. Density, 1.750; granulation, 123.	25	Eureka shell.	610	—10′	Rodman gauge. 5,000	509	5.00
	4	Mar. 20	Du Pont's hexagonal K. I. Density, 1,650; granulation, .72.	25	Eureka shell.	610	—10′	11,250	647	5.83
P. M.—Barometer, 29.773; thermometer, 19.9; humidty, 66.	5	Mar. 20	Du Pont's sphero-hexagonal I. B. C. Density, 1.728; granulation, 123.	25	Eureka shell.	610	—10′	7,000	553	5.35
	6	Mar. 20	Du Pont's hexagonal K. I. Density, 1 650; granulation, .72.	35	Eureka shell.	610	—10′	21,500	812	6.28
	7	Mar. 20		40	Eureka shell.	610	—10′	24,500	874	6.33

at Sandy Hook, N. J., from March 19 *to June* 26, 1885.

Wind—strength and direction.			
From front and right 48°; 18 miles an hour.	....	Star gauged: Fired into sand butt. Fifteen gallons oil in cylinder.	Sabot recovered with marks of rifling well defined. Shell left the sand butt without breaking.
From rear and right, 87°; 30 miles an hour.	....	Fired into sand butt. Sixteen gallons oil in cylinder.	Sabot stripped and did not take grooves well.
	....	Fired into sand butt.	
	....	Fired into sand butt.	
From rear and right, 87°; 40 miles an hour.	....	Fired into sand butt	Shell recovered. Sabot did not take grooves well.
	....	Fired into sand butt	Sabot recovered. Showing well-defined marks of the rifling.
	....	Fired into sand butt. Mortar star gauged (two warning charges fired).	Sabot recovered. Showing well defined marks of the rifling.

Record of firing with 12-inch muzzle-loading rifled mortar at Sandy

	Number of fire.	Time.	Powder.		Projectile.		Elevation.	Pressure per square inch of bore. (Rodman.)	Instrumental velocity, 89' from muzzle.	Recoil.
			Kind.	Weight.	Kind.	Weight.				
		1885.		*Lbs*		*Lbs*			*Feet.*	*Feet.*
A. M.—Barometer, 26.773; thermometer, 19.9; humidity, 66.	8	Mar. 21	Du Pont's sphero-hexagonal, I. B.C. Density, 1.728; granulation, 123.	50	Eureka shell.	610	—10′	22,000	931	6.42
	9	Mar. 21	Du Pont's sphero-hexagonal K. H.C. Density, 1.775; granulation, 123.	50	Eureka shell.	610	—10′	21,750	931	6.42
	10	Mar. 21	Du Pont's hexagonal K. I. Density, 1.650; granulation, .72.	25	Eureka shell.	610	10°	10,000	......	5.67
	11	Mar. 21		25	Eureka shell.	610	28°	10,750	......	5.08
	12	Mar. 21	Du Pont's sphero-hexagonal I. B.C. Density, 1.728; granulation, 123.	52	Eureka shell.	610	28°	26,750	......	6.08
P. M.—Barometer, 30.189; thermometer, 57.9; humidity, 42.	13	Apr. 1	Du Pont's sphero-hexagonal K. H.C. Density, 1.775; granulation, 123.	52	Eureka shell.	610	28°	20,400	90′ 2″ from muz.	6.29
	14	Apr. 1		30	Eureka shell.	610	28°	8,000	......	6.25

Hook, N. J., from March 19 *to June* 26, 1885—Continued.

Wind—strength and direction.			
From rear and right 43°; 28 miles an hour.	....	Fired into sand butt.	
	....	Fired into sand butt.	
From rear, 28 miles an hour.	Good flight.	To sea. Time of flight 7½ seconds.	Density of loading for 25 pounds of powder, 0.411. Density of loading for 35 pounds of powder, 0.575. Density of loading for 40 pounds of powder, 0.658. Density of loading for 50 pounds of powder, 0.823. Density of loading for 52 pounds of powder, 0.856.
	Good flight.	To sea. Time of flight 19½ seconds.	
....	Good flight.	To sea. Time of flight 28½ seconds.	
			Range (yards).
From rear and right, 47°; 14 miles an hour.	Good flight.	Fired to sea. Time of flight, 28 seconds..	7,084
	Tumbled ...	Fired to sea. Time of flight, 18½ seconds..	4,764

Record of firing with 12-inch muzzle-loading rifled mortar at Sandy

	Number of fire.	Time.	Powder.		Projectile.		Elevation.	Pressure per square inch of bore. (Rodman).	Instrumental velocity. 90′ 2″ from muzzle.	Recoil.
			Kind.	Weight.	Kind.	Weight.				
		1885.		*Lbs*		*Lbs*			*Feet.*	*Feet.*
A. M.—Barometer, 29.823; thermometer, 47.2; humidity, 68.	15	Apr. 30	Du Pont's hexagonal M.W. Density, 1.725; granulation, .72.	25	Eureka shell (new).	610	—10′	8, 750	617	4. 50
	16	Apr. 30	Du Pont's hexagonal M.V. Density, 1.700; granulation, .72.	25	Eureka shell (new).	610	— 8′	10, 750	642	4. 50
P. M.—Barometer, 29.724; thermometer, 65.4; humidity, 43.	17	Apr. 30		52	Eureka shell (new).	610	— 8′	37, 500	1, 031	5. 50
	18	Apr. 30		25	Eureka shell (new).	610	60°	9, 975	......	1. 62
	19	Apr. 30		25	Eureka shell (new).	610	60°	10, 200	......	1. 50
	20	Apr. 30		25	Eureka shell (new).	610	60°	10, 650	......	1. 50
P. M.—Barometer, 29 959; thermometer, 53.2; humidity, 66.	21	May 5	Du Pont's hexagonal M. W. Density, 1.725; granulation, .72.	25	Eureka shell (new).	610	60°	8, 600	......	1. 50
	22	May 5		25	Eureka shell (new).	610	60°	8, 500	......	1. 50
A. M.—Barometer, 29.876; thermometer, 48.2; humidity, 90.	23	May 6		52	Eureka shell (new).	610	—12′	33, 750	114′ 8″ from muz. 1, 017	5. 50
	24	May 6		50	Eureka shell (new).	610	—15′	32, 000	991	5. 42
	25	May 6		45	Eureka shell (new).	610	—15′	25, 750	926	5. 25
P. M.—Barometer, 30.157; thermometer, 54.1; humidity, 81.	26	May 13	Du Pont's sphero-hexagonal I. B. C. Density, 1.728; granulation, 123.	26	Eureka shell (new).	610	—10′	6, 650	89′ 8″ from muz. 591	4. 58
A. M.—Barometer, 29.996; thermometer, 50.1; humidity, 65.	27	May 14		26	Eureka shell (new).	610	73°	7, 350	......	1. 00
P. M.—Barometer, 29 996; thermometer, 50.1; humidity, 65.	28	May 14		26	Eureka shell (new).	610	73°	9, 500	......	0. 33

Hook, N. J., from March 19 *to June* 26, 1885—Continued.

Wind—strength and direction.			
		Before the following round, three of the four holes in piston-head closed and two others bored (15 gallons oil in cylinder):	
From rear and right, 43°; 10 miles an hour.	....	Fired into sand butt	Marks of rifling on sabot fairly well defined.
	....	Fired into sand butt......................	Marks of rifling on sabot well defined.
From rear and right, 87°; 10 miles an hour.	....	Fired into sand butt.	
			Range (yards).
From rear and right, 45°; 16 miles an hour.	Good flight .	Fired over water. Time of flight lost.....	4,296
	Good flight .	Fired over water. Time of flight, 34¾ seconds.	4,261
	Good flight .	Fired over water. Time of flight, 34¾ seconds.	4,232
From front and right, 45°; 20 miles an hour.	Good flight .	Fired over water. Time of flight, 33¾ seconds.	
	Good flight .	Fired over water. Time of flight, 33¾ seconds.	
From front and right, 3°; 10 miles an hour.	....	Fired into sand butt.	
	....	Fired into sand butt.	
	....	Fired into sand butt.	
From front and left, 87°; 20 miles an hour.		Gun star gauged.	
	....	Fired into sand butt......................	Sabot recovered, showing marks of rifling fairly well defined.
			Range (yards).
From rear and left, 45°; 35 miles an hour.	Good flight .	Fired over water. Time of flight, 37 seconds.	1,939
From rear and left, 45°; 28 miles an hour.	Good flight .	Fired over water. Time of flight, 36 seconds.	1,852

Record of firing with 12-inch muzzle-loading rifled mortar at Sandy

	Number of fire.	Time.	Powder.		Projectile.		Elevation.	Pressure per square inch of bore. (Rodman)	Instrumental velocity 89′ 8″ from muzzle.	Recoil.
			Kind.	Weight.	Kind.	Weight.				
		1885.		*Lbs*		*Lbs*			*Feet.*	*Feet.*
P. M.—Barometer, 30.041; thermometer, 67.3; humidity, 50.	29	May 15	Du Pont's spherohexagonal I.B.C. Density, 1.728; granulation, 123.	26	Eureka shell (new).	610	28°	....	......	3.75
	30	May 15		26	Eureka shell (new).	610	28°	....	......	3.92
	31	May 15		26	Eureka shell (new.)	610	28°	....	......	3.94
A. M.—Barometer, 30.099; thermometer, 55.2; humidity, 72.	32	May 29	Du Pont's hexagonal M. W. Density, 1.725; granulation, 72.	47	Eureka shell. Sabots reduced at Sandy Hook.	610	28°	26,500	......	4.75
	33	May 29		26		610	28°	8,250	......	3.92
	34	May 29		21		610	28°	7,000	......	3.67
	35	May 29	Du Pont's spherohexagonal I. B. C. Density, 1.728; granulation, 123.	52		610	28°	25,250	......	4.25
	36	May 29		26		610	28°	6,000	......	3.67
	37	May 29		21		610	28°	9 000	......	3.25
A. M.—Barometer, 30.184; thermometer, 68.8; humidity, 77.	38	June 26	De Pont's hexagonal M. V. Density, 1.700; granulation, 72.	25	Eureka shell (new).	610	—8′	9,500	90″ from muz. Lost.	4.50
	39	June 26		25	Eureka shell (new).	610	—8′	12,750	648	4.42
	40	June 26	Du Pont's hexagonal M.W. Density, 1.725; granulation, 72.	48	Eureka shell (new).	610	—8′	31,500	970	5.33
	41	June 26	Du Pont's hexagonal M.V. Density, 1.700; granulation, 72.	25	Eureka shell (new).	610	28°	11,500	......	4.04
	42	June 26		25	Eureka shell (new).	610	28°	11,250	......	4.16
	43	June 26	Du Pont's hexagonal M.W. Density, 1.725; granulation, 72.	48	Eureka shell (new).	610	28°	29,750	......	5.08
	44	June 26		48	Eureka shell (new).	610	28°	30,750	......	5.00

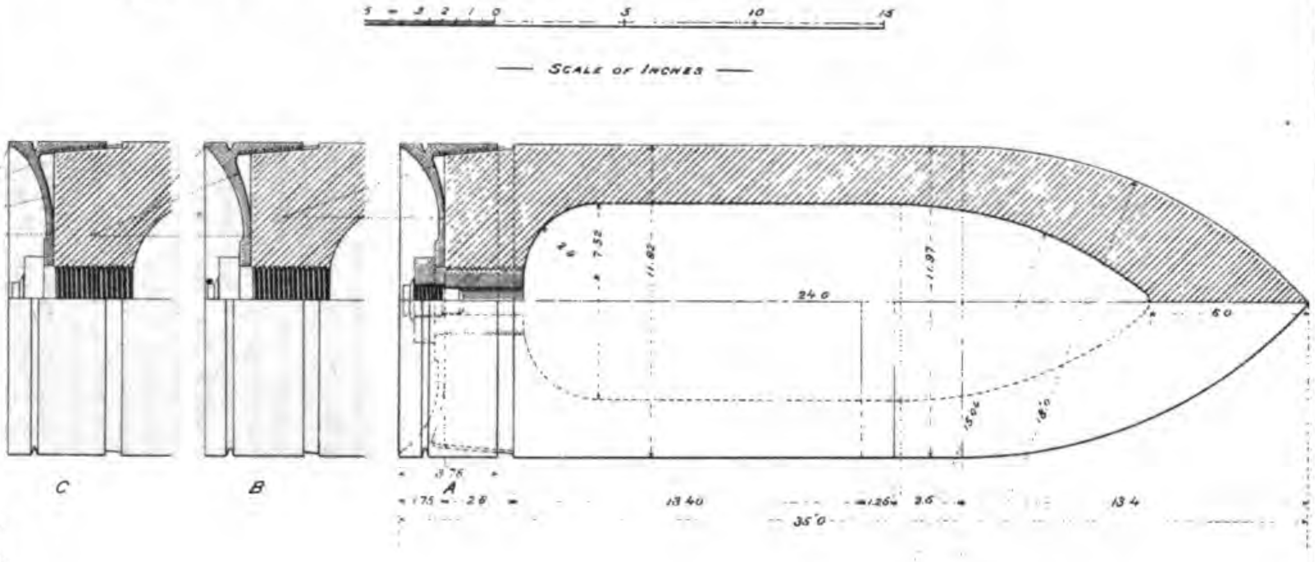
Hook, N. J., from March 19 *to June* 26, 1885—Continued.

Wind—strength and direction.			Range (yards).
From front; 4 miles an hour.	Good flight .	Fired over water. Time of flight, 17½ seconds............	2, 647
	Tumbled ...	Fired over water. Time of flight, 16½ seconds	2, 460
	Good flight	Fired over water. Time of flight, 17¼ seconds	2, 829
From front and left, 80°; 16 miles an hour.	Good flight	Fired over water. Time of flight, 27¼ seconds.	
	Tumbled ...	Fired over water. Time of flight, 17¾ seconds.	
	Tumbled ...	Fired over water. Time of flight, 15 seconds.	
	Good flight .	Fired over water. Time of flight, 27¾ seconds.	
	Tumbled ...	Fired over water. Time of flight, 16 seconds.	
	Tumbled ...	Fired over water. Time of flight, 14 seconds.	
From front; 11 miles and hour.	....	Fired into sand butt to try powder.	
	....	Fired into sand butt to try powder.	
	....	Fired into sand butt to try powder.	
From front and right, 43°; 11 miles an hour.	Good flight .	Fired over water for range. Time of flight, 19½ seconds..	3, 326
	Good flight .	Fired over water for range. Time of flight, 19¼ seconds..	3, 390
	Good flight .	Fired over water for range. Time of flight, 27¾ seconds..	7, 228
	Good flight .	Fired over water for range. Time of flight, 28 seconds...	7, 048

Table showing enlargements of bore of 12-inch muzzle-loading rifled mortar.

Inches from muzzle.	Original diameter of bore.	Enlargement of bore after—			Inches from muzzle.	Original diameter of bore.	Enlargement of bore after—		
		7 rounds.	12 rounds.	25 rounds.			7 rounds.	12 rounds.	25 rounds.
	Inches.	*Inches.*	*Inches.*	*Inches.*		*Inches.*	*Inches.*	*Inches.*	*Inches.*
88	12.006	0.000	0.000	0.000	56	12.006	—0.002	—0.002	—0.001
87	12.006	.000	.000	.000	54	12.006	—.001	—.002	—.001
86	12.006	.000	.000	—.001	52	12.007	—.002	—.002	—.001
85	12.006	.000	.000	—.001	50	12.007	—.002	—.002	—.001
84	12.006	.000	.000	—.001	48	12.007	.000	—.002	—.001
83	12.006	.000	.000	—.001	46	12.007	.000	—.002	—.001
82	12.006	.000	.000	—.001	44	12.007	.000	—.001	—.001
81	12.006	.000	—.001	—.001	42	12.007	.000	—.001	—.001
80	12.006	.000	—.001	—.001	40	12.007	.000	—.001	—.001
79	12.006	.000	—.001	—.001	38	12.007	.000	—.001	—.001
78	12.006	.000	—.001	—.001	36	12.008	—.001	—.002	—.001
77	12.006	.000	—.001	—.001	34	12.008	.000	—.002	—.001
76	12.006	.000	—.001	—.001	32	12.008	.000	—.002	—.002
75	12.006	.000	—.001	—.001	30	12.008	.000	—.002	—.002
74	12.006	.000	—.001	—.001	28	12.008	.000	—.002	—.002
73	12.006	—.001	—.001	—.001	26	12.007	.001	.000	—.001
72	12.006	.000	—.001	—.001	24	12.007	.001	.000	.000
71	12.006	.000	—.001	—.001	22	12.007	.001	.000	.000
70	12.006	.000	—.001	—.001	20	12.007	.001	.000	.001
69	12.006	.000	—.001	—.001	18	12.007	.001	.001	.001
68	12.006	.000	—.001	—.002	16	12.007	.001	.001	.001
67	12.006	—.001	—.001	—.002	14	12.007	.002	.001	.001
66	12.006	—.001	—.001	—.001	12	12.007	.002	.001	.001
65	12.006	—.001	—.001	—.001	10	12.007	.003	.001	.001
64	12.006	—.001	—.001	—.001	8	12.007	.003	.002	.001
63	12.006	—.001	—.001	—.001	6	12.007	.003	.002	.001
62	12.006	—.001	—.001	—.001	4	12.009	.001	.000	—.001
61	12.006	—.001	—.001	—.001	2	12.011	.000	—.002	—.001
60	12.006	—.001	—.001	—.001	1	12.012	.002	—.001	—.002
58	12.006	—.001	—.002	—.001					

SHELL FOR 12 INCH M.L. RIFLED MORTAR



ORDNANCE BOARD U.S.A.
GOVERNORS ISLAND SEPTEMBER 30TH 1885.

Appendix 18—[illegible]

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APPENDIX 20.

PROGRESS REPORT ON THE TRIAL OF THE 12-INCH BREECH-LOADING RIFLE (CAST IRON). BY THE ORDNANCE BOARD.

The gun, it is assumed, is described in the construction report of the inspecting officer stationed at the South Boston foundry.

Before being turned over to the Board it was fired five proof rounds under instructions given to the commanding officer of New York arsenal. In a letter dated Ordnance Office, April 8, 1885, the Board was directed, after the proof rounds had been fired from the gun, to continue the firing by testing German cocoa powder, gradually increasing the charges until 265 pounds had been fired with a shot weighing 800 pounds. Experimental powders, furnished by Du Pont & Co., were also fired under directions given by the Chief of Ordnance from time to time.

The carriage on which the piece is at present mounted is of the Krupp pattern, but as it is not to be used for further firing of this piece it does not require description here.

The projectiles were cored shot, weighing 700, 750, and 800 pounds, one-half of each being provided with single and one-half with double copper bands. The bands, it is understood, are forced into under-cut grooves by hammering, and then turned off to the proper diameter. Two kinds of metal were used for the single-band projectiles, viz, copper and an alloy of copper and zinc. The rounds from 19 to 23, both inclusive, were fired with the alloy bands. The first two projectiles (rounds 19 and 20) were fired into the sand butt and recovered.

The bands were sharply marked, but the metal of the bands did not seem to flow as smoothly and regularly as in the simple copper bands. This, however, appeared to exercise no perceptible influence on the natures of the flights, as the sound of the projectiles fired in rounds 21, 22, and 23 (which were furnished with similar bands denominated C) indicated that the flight was regular. As it is stated that band C is cheaper than the others, it would seem, as far as the limited experience so far gained can be depended upon, that a number of shot similarly banded should be furnished for the further test of this gun.

The powders used by the board were of two kinds, viz, German cocoa powder, density 1.863, and Du Pont's brown prismatic powder. The prisms of the German and of Du Pont's powder are hexagonal, about 0.97 inch long and 1.53 inches wide, as measured from corner to corner on the upper faces. They contain a single axial perforation, about 0.37 inch in diameter. The Du Pont's powder first received (type N. C.) had a density of 1.874, the last received (type N. M.) a density of 1.833. Charges of German powder, 132.5 pounds in weight, were built up carefully in tightly-fitting silk bags, choked and tied at the top. A portion of the bottom layer in each bag was composed of black prismatic grains, each having seven perforations.

A piece of fabric with sieve-like structure was inserted in the central portion of the bottom of the bag to insure easy ignition.

The charges of Du Pont's powder had a number of black prismatic grains in the lower layer, and the bag, made of serge, had two cuts crosswise in the bottom after it was filled, to facilitate ignition.

The trial of the gun by the Ordnance Board commenced with round number 6, fired June 25, 1885. A charge of 225 pounds of cocoa powder was fired with a double-band shot weighing 700 pounds, the highest indicated pressure being 25,550 pounds.

The charge was then increased to 245 pounds, and to enlarge the air-space a single-band shot was used. When the charge with a single-band shot weighing 700 pounds was further increased to 265 pounds the maximum pressure indicated was 30,250 pounds. Retaining this charge of 265 pounds the weight of the shot was increased to 750 pounds, then to 800 pounds, the pressure in the latter case being 31,400 pounds per square inch, and the instrumental velocity at 174′ 1″ from the muzzle was 1,703 feet, corresponding to a muzzle velocity of about 1,710 feet a second. The best results obtained with 265-pound charges of Du Pont's N. M. powder and an 800-pound projectile were in the twentieth round, when the muzzle velocity was 1,705.′6 with a pressure of 26,375 pounds. The maximum pressure per square inch with N. M. powder was 27,700, the minimum was 25,150 pounds, and the mean of six rounds was 26,258 pounds. The maximum muzzle velocity per second was 1,705.6 feet. The minimum was 1,683, and the mean of six rounds was 1,691.1 feet.

In the last five rounds a number of partially burned grains were found on the ground after firing.

The firings above referred to, as well as subsequent firings, made to test the quality of powders manufactured by Du Pont & Co., are given in the accompanying firing records. As up to this time neither the number nor quality of the bands to be used on the shot, nor the nature of the powder for subsequent test of the gun have been determined, a progress report only can be made.

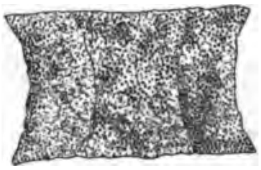
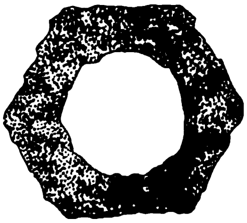
After firing a certain lot of Du Pont's powder, which gave low velocities and a maximum pressure of 23,850 pounds, many partially burned grains were found; a number of these grains retained a form quite similar to their original one. The central cavity was enlarged, the length of the grain diminished, the faces were slightly concave, the angles were less concave than the faces, but the particles of the grain remained connected together as at first. In other words, these grains which had been fired were not broken up into irregular fragments as it has sometimes been asserted would be the case. It is possible, although hardly probable, that some of them commenced to burn only after they were ejected from the gun, but the deep, irregular "pits" in the surfaces seemed to indicate that they had burned under considerable pressure.

T. G. BAYLOR,
Colonel of Ordnance, President of Board.
GEO. W. McKEE,
Major of Ordnance.
CHARLES SHALER,
Captain of Ordnance.

Record of firing with 12-inch experimental cast-iron breech-loading

	Number of fire.	Time.	Powder.		Projectile.		Elevation.	Pressure per square inch of bore, new crusher.	Instrumental velocity 126' 7½" from muzzle.	Recoil.
			Kind.	Weight.	Kind.	Weight.				
		1885.		*Lbs.*		*Lbs.*	° ′	*Pounds.*	*Feet.*	*Feet.*
A. M.—Barometer, 30.222; thermometer, 66.3; humidity, 57.1.	1	June 19	Du Pont's hexagonal I. V. Density, 1,735; granulation, 11.	150	Hotchkiss (new).	700	35	19,600	1,370	3.58
P. M.—Barometer, 30.194; thermometer, 77.3; humidity, 50.	2	June 19		150		700	44	19,350	1,351	3.79
	3	June 19		150		700	44	19,675	1,373	4.00
									126' 5¼"	
P. M.—Barometer, 30.032; thermometer, 70.4; humidity, 40.	4	June 23	Du Pont's hexagonal I. T. Density, 1,725; granulation, 30.	150		700	55	24,600	1,430	4.52
	5	June 23		150		700	60	47,250	1,495	4.67
									126' 6¼"	
A. M.—Barometer, 30.216; thermometer, 74.6; humidity, 48.	6	June 25	German cocoa powder.	225	Double band B.	700	1 05	25,550 A 20,850 B	1,666	5.42
									174'	
P. M.—Barometer, 30.163; thermometer, 80.1; humidity, 55.	7	June 25		245	Single band A.	700	1 05	26,600 A 21,550 B	1,727	5.56
	8	June 25		265		700	1 07	30,250 A 29,725 B	1,796	5.62
									174' 1"	
	9	June 25		265		750	1 10	31,975 A 32,000 B	1,753	5.90
	10	June 25		265		800	1 10	31,400 A 31,400 B	1,703	5.90
A. M.—Barometer, 29.876; thermometer, 69.4; humidity, 67.	11	July 3	Du Pont's brown prismatic N. C.	225	Double band B.	700	1 10	18,200 A 18,250 B	1,508	4.16
	12	July 3		245		700	1 10	20,425 A 20,200 B	1,585	4.56
	13	July 3		265	Single band A.	700	1 10	21,825 A 22,250 B	1,622	4.96
A. M.—Barometer, 30.075; thermometer, 78.3; humidity, 72.	14	July 8		265	Double band B.	800	1 10	23,625 A 23,850 B	1,576	5.42
	15	July 8	German cocoa powder.	265		750	6 00	32,400 A 32,325 B	....	5.42
	16	July 8		265	Single band A.	750	6 00	28,200 A 31,700 B	....	5.42

rifle at Sandy Hook, N. J., from June 19 *to September* 29, 1885.

Wind, strength, and direction.	Special remarks about each fire, such as effect on piece, sound of projectile in flight, scattering of fragments, &c.
From front and left 43°; 10 miles an hour.	Fired into sand-butt; 24½ gallons of oil in each cylinder. Density of loading 0.582 { Rear of chamber for length of 12½ inches closed with wood. Density of loading 0.619 { Rear of chamber for length of 15 inches closed with wood. Density ot loading 0.785 { Rear of chamber for length of 25 inches closed with wood. Gun closed and opened easily; no escape of gas.
From rear and right 87°; 12 miles an hour.	Density of loading 0.785 { Rear of chamber for length of 25 inches closed with wood. Density of loading 0.906 { Rear of chamber for length of 30 inches closed with wood.
From front and right 48°; 4 m. an hour.	Two pressure plugs placed in mushroom-head, marked A and B. Block closed easily; opened with little difficulty; no escape of gas.
From front and right 48°; 8 miles an hour.	Fired into sand-butt to try powder. Block opened easily, but closed with difficulty; no escape of gas. 
From rear and right 87°; 11 miles an hour.	Before firing clamp on rear of obturator stem replaced by screw-nut and asbestos gas-check, lined as well as covered with asbestos cloth. Opened with ease by one man after firing, and similarly closed after loading, but with more difficulty. 
From rear and right 87°; 6 m. an hour.	Considerable quantity of partially consumed grains of powder.
From rear and right 45°; 6 miles an hour.	Good flight. Fired over water for range. Time of flight, 11¼ seconds .... *Range (yards).* 5,329 Good flight. Fired over water for range. Time of flight, 11¼ seconds .... Lost.

Record of firing with 12-*inch experimental cast-iron breech-loading rifle*

	Number of fire.	Time.	Powder.		Projectile.		Elevation.	Pressure per square inch of bore, crusher.	Instrumental velocity 124′ 8″ from muzzle.	Recoil.
			Kind.	Weight.	Kind.	Weight.				
		1885.		*Lbs*		*Lbs.*	° ′	*Pounds.*	*Feet.*	*Feet.*
P. M.—Barometer, 29.947; thermometer, 81.3; humidity, 52.	17	July 15	German cocoa powder.	265	Double band B.	750	6 00	....	....	5.05
A. M.—Barometer, 30.088; thermometer, 80.1; humidity, 68.8.	18	July 16		265	Single band A.	750	6 00	....	....	5.05
P. M.—Barometer, 30.039; thermometer, 57.8; humidity, 92.	19	Sept. 10	Du Pont's brown prismatic powder. Received Sept. 9, 1885.	245	Single band C. (Cast metal.)	800	1 10	23,700 A 24,100 B	1,639	5.79
	20	Sept. 10		265		800	1 10	26,375 A 26,225 B	1,700	6.12
									Horizontal: 184′ 11¼″	
P. M.—Barometer, 30.115; thermometer, 72.4; humidity, 80.	21	Sept. 29	Du Pont's brown prismatic N. M. Density, 1.833.	265	Single band C. (Cast band).	800	4 00	27,700 A 27,550 B	1,687	6.21
	22	Sept. 29		265		800	4 00	25,200 A 27,350 B	1,679	6.25
	23	Sept. 29		265		800	4 00	25,200 A 27,300 B	1,681	6.25
	24	Sept. 29		265	Single band A.	800	4 00	25,150 A 25,650 B	1,679	6.33
	25	Sept. 29		265		800	4 00	25,750 A 25,650 B	1,675	6.33

at Sandy Hook, N. J., from June 19 *to September* 29, 1885—Continued.

Wind, strength, and direction.	Flight.	Time of flight.	Special remarks about each fire, such as effect on piece, sound of projectile in flight, scattering of fragments, &c.	*Range (yards).*	*Deviation (yards).*	
		Sec'ds				
From front and right 45°; 16 miles an hour.	Good flight.	11⅜	Fired over water for range	5,304		
From rear and right 45°; 5 miles an hour.	Good flight.	11⅜	Fired over water for range Before firing this round the unlocking lever lengthened 4 inches; translating lever, 3 inches.	5,292		
From front and left 87°; 18 miles an hour.	....	......	Fired into sand butt. Cartridge in two sections; 13 prisms of black powder at base of each.			A small amount of unconsumed powder picked up.
	....	......				A small amount of unconsumed powder picked up. Block unlocked partially at discharge.
From front and right 25°; 8 miles an hour.	Good flight.	7½	Fired over water for range. A considerable amount of unconsumed powder.	3,641	17.5 right.	The guide of vent-shield bound, making it very difficult to open block after firing. Vent-shield removed before firing.
	Good flight	7¾		3,650	12.5 right.	
	Good flight.	7½		3,739	28.2 left.	
	Good flight.	8		3,751	51.2 left.	
	Good flight.	7⅝		3,702	18.1 left.	

Table of enlargements of 12-inch experimental cast-iron breech-loading rifle.

Inches from muzzle.	Original diameter of bore.	Enlargements of bore after—		
		A total of 5 rounds.	A total of 10 rounds.	A total of 25 rounds.
268	12.002	−0.001	0.005	0.024
267	12.001	−0.001	0.005	0.023
266	12.000	0.000	0.005	0.021
265	12.000	0.000	0.005	0.020
264	12.000	0.000	0.004	0.019
263	12.000	0.000	0.004	0.017
262	12.000	0.000	0.004	0.016
261	12.000	0.000	0.004	0.015
260	12.000	0.000	0.004	0.015
259	12.000	0.000	0.004	0.015
258	12.000	0.000	0.004	0.015
257	12.000	0.000	0.004	0.013
256	12.000	0.000	0.004	0.013
255	12.000	0.000	0.004	0.013
254	12.000	0.000	0.004	0.013
253	12.000	0.000	0.004	0.013
252	12.000	0.000	0.004	0.013
251	12.000	0.000	0.004	0.011
250	12.000	0.000	0.004	0.011
249	12.000	0.000	0.004	0.010
248	12.000	0.000	0.004	0.009
247	12.000	0.000	0.004	0.009
246	12.000	0.000	0.004	0.009
245	12.001	−0.001	0.003	0.008
244	12.001	0.000	0.003	0.008
243	12.001	0.000	0.003	0.009
242	12.001	0.000	0.002	0.008
241	12.001	0.000	0.002	0.007
240	12.001	0.000	0.002	0.007
239	12.001	0.000	0.002	0.006
238	12.001	0.000	0.002	0.003
237	12.000	0.001	0.003	0.005
236	12.000	0.001	0.003	0.005
235	12.000	0.001	0.003	0.005
234	12.000	0.001	0.003	0.005
233	12.000	0.001	0.003	0.005
232	12.000	0.001	0.003	0.004
231	12.000	0.001	0.003	0.004
230	12.000	0.001	0.003	0.004
229	12.000	0.001	0.003	0.005
228	12.000	0.001	0.003	0.004
227	12.000	0.002	0.003	0.004
226	12.000	0.002	0.003	0.004
225	12.001	0.001	0.002	0.003
224	12.001	0.000	0.002	0.004
223	12.002	−0.001	0.002	0.003
222	12.002	−0.001	0.002	0.003
221	12.002	−0.001	0.002	0.003
220	12.002	−0.001	0.002	0.002
219	12.002	0.000	0.002	0.002
218	12.002	0.001	0.002	0.002
217	12.002	0.001	0.002	0.002
216	12.002	0.001	0.002	0.003
215	12.002	0.001	0.002	0.003
214	12.002	0.001	0.002	0.002
213	12.002	0.001	0.002	0.002
212	12.002	0.001	0.002	0.002
211	12.002	0.000	0.002	0.002
210	12.003	−0.001	0.001	0.001
209	12.003	−0.001	0.001	0.001
208	12.003	−0.001	0.001	0.001
207	12.002	0.000	0.002	0.002
206	12.003	−0.001	0.001	0.001
205	12.003	−0.001	0.001	0.001
204	12.003	0.000	0.001	0.000
203	12.003	0.000	0.001	0.000
202	12.003	0.000	0.001	0.000
201	12.003	0.000	0.001	0.001
200	12.003	0.001	0.001	0.001
199	12.003	0.001	0.001	0.001
198	12.003	0.001	0.000	0.001
197	12.003	0.001	0.000	0.001
196	12.003	0.001	0.000	0.001
195	12.003	0.001	0.000	0.001
194	12.004	−0.002	−0.001	0.000
193	12.004	−0.002	−0.001	0.000
192	12.004	−0.002	−0.001	0.000
191	12.003	−0.001	−0.001	0.001

Table of enlargements of 12-*inch experimental cast-iron breech-loading rifle*—Continued.

Inches from muzzle.	Original diameter of bore.	Enlargements of bore after—		
		A total of 5 rounds.	A total of 10 rounds.	A total of 25 rounds.
190	12.003	−0.002	−0.001	0.001
189	12.003	−0.001	−0.001	0.001
188	12.003	−0.002	−0.001	0.001
187	12.003	−0.002	−0.001	0.001
186	12.003	−0.002	−0.001	0.001
185	12.003	−0.002	−0.001	0.001
184	12.003	−0.002	−0.001	0.001
183	12.003	−0.002	−0.001	0.001
182	12.003	−0.002	0.000	0.001
181	12.003	−0.002	0.000	0.001
180	12.004	−0.001	0.000	0.000
179	12.004	−0.001	0.000	0.000
178	12.004	−0.001	0.000	0.000
177	12.004	−0.001	0.000	−0.001
176	12.004	−0.001	0.000	−0.001
175	12.004	−0.001	0.000	0.000
174	12.004	−0.001	0.000	0.000
173	12.004	−0.001	0.000	0.000
172	12.004	−0.001	0.000	0.000
171	12.004	−0.001	0.000	0.000
170	12.004	−0.001	0.000	0.000
165	12.004	−0.001	0.000	−0.001
160	12.003	−0.001	0.000	0.000
155	12.003	−0.001	0.000	0.000
150	12.004	−0.001	0.000	−0.001
145	12.004	−0.001	0.000	−0.001
140	12.004	−0.001	0.000	−0.001
135	12.004	−0.001	−0.001	−0.001
130	12.003	−0.000	0.000	0.000
125	12.003	−0.001	0.000	0.000
120	12.003	−0.001	0.001	0.000
115	12.003	−0.002	0.000	0.000
110	12.003	−0.002	0.000	0.000
105	12.003	−0.002	0.000	0.000
100	12.003	−0.002	0.000	0.000
95	12.003	−0.002	0.000	0.000
90	12.003	−0.002	0.000	0.000
85	12.003	−0.001	0.000	0.003
84	12.003	0.000	0.001	0.005
83	12.004	0.000	0.001	0.005
82	12.005	−0.001	0.000	0.004
81	12.005	0.000	0.002	0.005
80	12.006	0.001	0.003	0.004
79	12.008	0.000	0.003	0.004
78	12.009	0.000	0.002	0.004
77	12.009	0.000	0.002	0.005
76	12.011	−0.001	0.001	0.002
75	12.011	−0.001	0.001	0.001
74	12.010	−0.001	0.002	0.003
73	12.011	0.000	0.001	0.001
72	12.011	−0.001	0.000	0.001
71	12.010	0.000	0.001	0.002
70	12.011	−0.002	0.000	0.001
69	12.009	−0.001	0.001	0.003
68	12.008	−0.001	0.001	0.001
67	12.007	−0.001	0.000	0.001
66	12.005	−0.001	0.001	0.001
65	12.003	0.000	0.001	0.002
60	12.005	−0.001	0.000	0.000
55	12.005	−0.002	0.000	−0.001
50	12.003	−0.001	0.001	−0.001
45	12.004	−0.002	−0.001	−0.002
40	12.003	0.000	0.000	−0.001
35	12.003	0.000	0.000	−0.001
30	12.003	0.000	0.000	−0.001
25	12.003	0.000	0.000	−0.001
20	12.003	0.000	0.000	−0.001
15	12.003	0.000	0.000	−0.001
10	12.003	0.000	0.000	−0.001
5	12.004	−0.001	−0.001	−0.001
1	12.004	−0.001	0.000	−0.001

Table of enlargements of chamber of 12-inch experimental cast-iron breech-loading rifle.

Inches from breech.	Original diameter of chamber.		Enlargement after 5 rounds.		Enlargement after 10 rounds.		Enlargement after 25 rounds.	
	Horizontal.	Vertical.	Horizontal.	Vertical.	Horizontal.	Vertical.	Horizontal.	Vertical.
77¾	13. 507	13. 507	−0. 002	−0. 003	−0. 001	−0. 002	0. 000	0. 000
77	13. 507	13. 507	−0. 002	−0. 003	−0. 001	−0. 002	0. 001	0. 001
76	13. 507	13. 508	−0. 002	−0. 004	−0. 002	−0. 003	0. 001	0. 000
75	13. 507	13. 508	−0. 002	−0. 003	−0. 002	−0. 003	0. 001	0. 000
74	13. 507	13. 508	−0. 002	−0. 003	−0. 002	−0. 003	0. 001	0. 000
73	13. 506	13. 507	−0. 002	−0. 002	−0. 001	−0. 002	0. 002	0. 000
72	13. 506	13. 506	−0. 002	−0. 002	−0. 002	−0. 002	0. 001	0. 000
71	13. 505	13. 506	−0. 001	−0. 002	−0. 001	−0. 002	0. 002	0. 000
70	13. 504	13. 506	−0. 001	−0. 002	−0. 001	−0. 002	0. 002	−0. 001
69	13. 503	13. 505	−0. 001	−0. 002	0. 000	−0. 001	0. 002	−0. 001
68	13. 503	13. 505	0 000	−0. 002	0. 000	−0. 001	0. 000	0. 000
67	13. 503	13. 505	0. 000	−0. 002	0. 000	−0. 001	0. 002	0. 000
66	13. 503	13. 505	0. 000	−0. 002	0. 000	−0. 001	0. 001	0. 000
65	13. 503	13. 504	0. 000	−0. 001	0. 000	−0. 001	0. 001	0. 001
64	13. 503	13. 505	−0. 001	−0. 002	0. 000	−0. 002	0. 001	0. 000
63	13. 503	13. 505	−0. 001	−0. 002	0. 000	−0. 002	0. 002	0. 000
62	13. 503	13. 505	−0. 001	−0. 002	0. 000	−0. 002	0. 001	0. 000
61	13. 503	13. 505	−0. 001	−0. 002	0. 000	−0. 002	0. 001	−0. 001
60	13. 503	13. 505	−0. 001	−0. 002	0. 000	−0. 002	0. 001	−0. 001
59	13. 503	13. 505	−0. 001	−0. 002	0. 000	−0. 002	0. 001	−0. 001
58	13. 504	13. 505	−0. 002	−0. 002	−0. 001	−0. 002	0. 000	−0. 001
57	13. 504	13. 505	−0. 001	−0. 002	−0. 001	−0. 002	0. 000	−0. 001
56	13. 504	13. 505	−0. 001	−0. 002	−0. 001	−0. 002	0. 000	−0. 001
55	13. 504	13. 505	−0. 001	−0. 002	0. 000	−0. 002	0. 000	−0. 001
54	13. 504	13. 504	−0. 001	−0. 001	0. 000	−0. 001	0. 001	0. 000
53	13. 504	13. 504	−0. 001	−0. 002	−0. 001	−0. 001	0. 001	0. 000
52	13. 504	13. 504	−0. 001	−0. 002	0. 000	−0. 001	0. 001	0. 000
51	13. 504	13. 504	−0. 001	−0. 002	0. 000	−0. 001	0. 001	0. 000
50	13. 504	13. 504	−0. 001	−0. 002	0. 000	−0. 002	0. 001	−0. 001
49	13. 504	13. 504	−0. 001	−0. 002	0. 000	−0. 001	0. 001	−0. 001
48	13. 504	13. 504	−0. 001	−0. 002	0. 000	−0. 001	0. 001	0. 000
47	13. 504	13. 504	−0. 001	−0. 001	0. 000	−0. 001	0. 001	−0. 001
46	13. 504	13. 504	−0. 001	−0. 001	0. 000	−0. 001	0. 000	−0. 001
45	13. 504	13. 504	−0. 001	−0. 001	0. 000	−0. 001	0. 000	−0. 001
44	13. 504	13. 504	−0. 001	−0. 001	0. 000	−0. 001	0. 000	−0. 001
43	13. 504	13. 504	−0. 001	−0. 001	0. 000	−0. 001	0. 000	0. 000
42	13. 503	13. 504	0. 000	−0. 001	0. 001	−0. 001	0. 001	0. 000
41	13. 503	13. 504	0. 000	−0. 001	0. 001	−0. 001	0. 002	0. 000
40	13 503	13. 504	0. 000	−0. 001	0. 001	−0. 001	0. 001	0. 000
39	13. 503	13. 504	0. 000	−0. 001	0. 001	−0. 001	0. 002	0. 000
38	13. 503	13. 504	0. 000	−0. 002	0. 001	−0. 001	0. 002	0. 000
37	13. 503	13. 504	0. 000	−0. 002	0. 001	−0. 001	0. 001	−0. 001
36	13. 503	13. 504	0. 000	−0. 002	0. 001	−0. 001	0. 001	−0. 001
35	13. 503	13. 504	0. 000	−0. 002	0. 001	−0. 001	0. 001	−0. 001
34	13. 503	13. 504	0. 000	−0. 002	0. 001	−0. 001	0. 001	−0. 001
33	13. 503	13. 504	0. 000	−0. 002	0. 001	−0. 001	0. 001	−0. 001
32	13. 503	13. 504	0. 000	−0. 002	0. 000	−0. 001	0. 001	−0. 001
31	13. 503	13. 504	−0. 001	−0. 002	0. 000	−0. 001	0. 001	−0. 001
30	13. 503	13. 504	−0. 001	−0. 002	0. 000	−0. 001	0. 001	0. 000
29	13. 503	13. 504	−0. 001	−0. 002	0. 000	+0. 001	0. 001	0. 000
28	13. 503	13. 504	−0. 001	−0. 002	0. 000	+0. 001	0. 001	0. 000
27	13. 503	13. 504	−0. 001	−0. 002	0. 000	0. 000	0. 001	0. 000
26	13. 503	13. 505	−0. 001	−0. 003	0. 000	−0. 001	0. 001	−0. 001
25	13. 503	13. 506	−0. 001	−0. 004	0. 000	−0. 002	0. 001	−0. 002
24	13. 503	13. 506	−0. 001	−0. 004	0. 000	−0. 002	0. 001	−0. 003
23	13. 503	13. 506	−0. 001	−0. 004	0. 000	−0. 003	0. 001	−0. 003
22	13. 563	13. 506	−0. 001	−0. 004	0 000	−0. 003	0. 001	−0. 002
21	13. 533	13. 534	−0. 017	−0. 030	0. 004	0. 017	....	....
20	13. 618	13. 614	−0. 011	−0. 010	0. 028	0. 024	....	....
19	13. 713	13. 713	−0. 018	−0. 017	0. 027	0. 020	....	....

APPENDIX 21.

FINAL FIRING AND RUPTURE OF THE 6-INCH MULTICHARGE GUN. BY THE ORDNANCE BOARD.

(2 plates.)

ORDNANCE BOARD, U. S. A., NEW YORK ARSENAL,
Governor's Island, N. Y. Harbor, December 29, 1884.

The CHIEF OF ORDNANCE, U. S. A.,
Washington, D. C.:

SIR: I have the honor to forward this day the firing and star gauge records of the 20 rounds fired from the 6 inch multicharge gun, since, in accordance with your instructions of October 22, 1884, it was strengthened. At the 20th round of this last series the casing of the gun was fractured, as shown in the accompanying plate. The crack made in the tube before this firing commenced did not extend materially, and the tube did not split in the vicinity of the ruptured jacket. A table showing the calculated data for the different rounds is likewise inclosed. The information embodied in this last inclosure has been furnished Mr. Haskell at his request.

For the Board.

Very respectfully, your obedient servant,

T. G. BAYLOR,
Colonel of Ordnance, President of Board.

Record of firing with 6-inch multicharge gun at Sandy

	No. of fire.	Time.	Powder.					Projectile.			Pressure, pounds per square inch of bore.						
			Breech.	First pocket.	Second pocket.	Third pocket.	Fourth pocket.	Kind.	Weight.	Elevation.	Breech.	First pocket.	Second pocket.	Third pocket.	Fourth pocket.	Instrumental velocity, 105' from muzzle.	Recoil.
		1884.							Lbs.	° ′						Ft.	Ft.
A. M.—Barometer, 30.281; thermometer, 37.8; humidity, 62.	34	Dec. 10	KN 17	KA 22	KR 22	KBA 22	KQ 22	4 cal.	155	2 30	Sub.	20,800	18,200	25,100	Sub.	1,535	4.21
			105														
P. M.—Barometer, 30.273; thermometer, 41.8; humidity, 91.	35	Dec. 10	KN 18	KA 23	KR 23	KBA 23	KQ 23	4 cal.	155	2 30	Sub.	25,150	20,600	28,700	20,400	1,571	4.29
			110														
	36	Dec. 10	KM 18	KAA 24	KR 24	KBA 24	KCA 24	3 cal.	109	2 30	22,000	20,100	19,400	25,800	23,200	1,776	3.58
			114														
A. M.—Barometer, 30.056; thermometer, 43.0; humidity, 68.	37	Dec. 11	KM 18	KR 24	KBA 24	KS 24	KT 24	3 cal.	111	4 30	25,300	20,250	22,000	29,000	27,000	1,842	3.89
			114														
P. M.—Barometer, 30.030; thermometer, 48.1; humidity, 67.	38	Dec. 11	KM 18	KR 24	KBA 24	KCA 23	KDA 22	3 cal.	111	4 30	*	19,400	23,300	25,700	24,450	1,895	3.58
			111														
	39	Dec. 11	KM 18	KR 24	KBA 24	KCA 23	KDA 22	4 cal.	155	4 30	*	20,100	22,000	27,350	25,700	1,750	3.99
			111														
	40	Dec. 11	KM 19	KR 25	KBA 25	KCA 24	KDA 23	3 cal.	111	4 30	30,050	20,400	23,400	27,900	25,550	1,942	3.71
			116														
																51′ 8″ from muzzle.	
A. M.—Barometer, 30.176; thermometer, 36.1; humidity, 59.	41	Dec. 16	KN 19	KR 26	KBA 25	KCA 23	KDA 22	4 cal.	155	8 30	20,000	20,100	27,800	27,400	28,100	1,604	4.58
			115														
	42	Dec. 16	KM 19	KR 27	KBA 26	KCA 24	KDA 23	3 cal.	111	8 30	31,550	24,700	27,400	27,350	25,750	1,909	4.19
			119														
P. M.—Barometer, 30.261; thermometer, 43.8; humidity, 59.	43	Dec. 16	KM 19	KR 27	KBA 25	KCA 23	KDA 22	4 cal.	152	8 30	31,300	26,150	26,000	27,825	25,100	1,796	4.19
			116														

* Not taken.

Hook, N. J., from December 10 *to December* 18, 1884.

Wind, strength and direction.	Pressure, pounds, per square inch of bore at— First loading hole.	Second loading hole.	Third loading hole.	Fourth loading hole.	Range.		Special remarks about each fire, such as effect on piece, sound of projectile in flight, scattering of fragments, &c.
					Yds.		Before round 34, three steel hoops were shrunk on forward portion of gun and a lead band attached to rear to overcome the muzzle preponderance.
From rear and left 45°, 14 miles an hour.	18,800	Sub.	18,800	Sub.	2,142	Fired over water.	The breech-cartridge was inclosed in a copper case which fitted in rear into the head of the obturator. In the base of the case, holes were cut to allow the ignition of the charge and for the pressure-plug. The case, though badly misshapen, was easily withdrawn after firing. No escape of gas at any pocket, but slight escape at third, and considerable at fourth, loading hole. The breech-block opened and closed easily at this and following rounds, and at no time was there any escape of gas at breech.
From rear; 8 miles an hour.	19,900	Sub.	Sub.	Sub.	2,162		A short copper case, 1½ inches long, replaced the larger case used in preceding round, and was used through the remainder of the firing.
	24,250	10,000	Sub.	20,000	2,397		
From front and right 74°, 14 miles an hour.	23,200	20,000	18,800	20,200	4,091		
From rear and right 76°; 20 miles an hour.	23,800	Sub.	Sub.	20,100	4,238		
	22,800	Sub.	Sub.	20,850	4,107		
	22,400	Sub.	Sub.	Sub.	4,480		No greater elevation being possible for the gun as mounted, the props and forks for traverse wheels were removed and the chassis lowered into skidding so as to have an upward inclination of 1° to the rear.
From rear and right 76°; 20 miles an hour.	Sub.	19,000	19,400	23,800	6,067		
	21,400	19,800	Sub.	20,000	6,672		Gas escaped around pressure-plug of fourth pocket.
From rear and right 76°; 20 miles an hour.	22,400	20,200	Sub.	20,200	6,645		Prop and traverse wheels replaced.

Record of firing with 6-inch multicharge gun at Sandy

	No. of fire.	Date.	Powder. Breech.	Powder. First pocket.	Powder. Second pocket.	Powder. Third pocket.	Powder. Fourth pocket.	Powder. Total	Projectile. Kind.	Projectile. Weight.	Projectile. Elevation.	Pressure, pounds, per square inch of bore, at— Breech.	First pocket.	Second pocket.	Third pocket.	Fourth pocket.	Instrumental velocity, 106' 9'' from muzzle.	Recoil.
		1884.								*Lbs*	° ′						*Feet.*	*Ft.*
P. M.—Barometer, 30.261; thermometer, 43.8; humidity, 59.	44	Dec. 16	KMA 19	KR 27	KBA 26	KCA 24	KDA 23	119	3 cal.	110	2 45	29,350	26,200	26,800	29,200	26,300	1,960	3.16
A. M.—Barometer, 29.914; thermometer, 39.2; humidity, 84.	45	Dec. 17	KMA 19	KR 27	KBA 26	KQ 24	KDA 23	119	3 cal.	110	2 53	31,000	25,450	28,400	22,000	26,050	1,952	2.75
A. M.—Barometer, 29.914; thermometer, 39.2; humidity, 84.	46	Dec. 17	KMA 19	KR 27	KBA 26	KQ 25	KDA 23	120	3 cal.	110	2 55	30,450	26,700	23,500	24,200	26,450	1,955	2.67
A. M.—Barometer, 29.914; thermometer, 39.2; humidity, 84.	47	Dec. 17	KMA 19	KR 27	KBA 26	KQ 25	KDA 23	120	3 cal.	110	2 55	29,400	21,600	21,400	22,400	25,200	1,930	3.16
P. M.—Barometer, 29.825; thermometer, 39.8; humidity, 76.	48	Dec. 17	KMA 19	KR 27	KBA 26	KQ 25	KDA 23	120	3 cal.	110	2 55	27,500	25,050	24,000	24,000	26,100	1,938	2.73
P. M.—Barometer; 29.825; thermometer, 39.8; humidity, 76.	49	Dec. 17	KMA 19	KR 27	KBA 26	KQ 25	KDA 23	120	3 cal.	110	2 55	29,900	24,000	25,000	21,600	24,500	1,942	[illegible]
P. M.—Barometer, 29.825; thermometer, 39.8; humidity, 76.	50	Dec. 17	KMA 19	KR 27	KBA 26	KQ 25	KDA 23	120	3 cal.	110	2 55	26,750	22,600	26,800	21,600	25,600	1,953	2.58
A. M.—Barometer, 30.105; thermometer, 26.1; humidity, 67.	51	Dec. 18	KMA 19	KR 27	KBA 26	KP 25	KDA 23	120	3 cal.	110	2 55	27,000	22,000	26,900	26,200	28,300	1,972	2.58
	52	Dec. 18	KMA 19	KR 27	KBA 26	KP 25	KDA 23	120	3 cal.	109	2 55	25,100	21,700	27,900	27,200	26,400	1,961	2.67
	53	Dec. 18	KMA 19	KR 27	KBA 25	KP 24	KDA 22	117	4 cal.	150	3 10	30,150	25,000	30,300	27,200	26,250	1,790	3.16

The flight of projectiles was good throughout. Where the term "Sub." appears in column of pressure, the pressure was less than 18,000 pounds per square inch.

Hook, N. J., from December 10 *to December* 18, 1884—Continued.

Wind, strength and direction.	Pressure, pounds, per square inch of bore, at—				Distance from center of target, in feet.				Distance from center of impact, in feet.				Special remarks about each fire, such as effect on piece, sound of projectile in flight, scattering of fragments, &c.
					Vertical.		Horizontal.		Vertical.		Horizontal.		
	First loading hole.	Second loading hole.	Third loading hole.	Fourth loading hole.	Above.	Below.	Right.	Left.	Above.	Below.	Right.	Left.	
From right, 16 miles.	25,900	20,500	Sub.	21,600	Fired at 3,000-yard target; sighting shot; struck 11 yards short.								
From front, 8 miles.	25,200	20,000	20,000	20,450	Fired at 3,000-yard target; sighting shot; struck 4' 6" right and 12' 6" below.								
From front and right 45°, 6 miles an hour.	26,500	21,000	Sub.	Sub.	0.58	.....	3.00	.....	3.52	.....	.....	1.43	Fired at 3,000-yard target. Target 30' by 40', made of 1" spruce boards. The housing of pressure plug of first loading hole broke off while being unscrewed, and the plug of the third loading hole was also badly damaged; both were removed and replaced by blanks. Unburnt powder picked up at the second frame.
From right, 5 miles an hour.	*	20,850	19,400	*	.....	1.50	.....	0.25	1.44	.....	.....	4.68	
From rear 7 miles an hour.	*	28,000	20,100	*	.....	13.00	11.00	.....	....	10.06	6.57	.....	
From right, 4 miles an hour.	*	19,600	Sub.	*	....	12.50	4.50	.....	....	9.56	0.07	.....	
From right, 5 miles an hour.	*	20,600	Sub.	*	0.75	....	13.83	.....	3.69	.....	9.40	.....	
From rear and right, 45°. 10 miles an hour.	*	*	20,800	*	1.34	.....	1.00	.....	4.28	.....	.....	3.43	
From rear and right, 45°. 12 miles an hour.	*	*	20,600	*	3.75	...	.....	2.07	6.69	.....	...	6.50	
					6.42	27.00	33.33	2.32	19.62	19.62	16.04	16.04	
					20.58 ÷ 7 = 2.94		31.01 ÷ 7 = 4.43		39.24 ÷ 7 = 5.61		32.08 ÷ 7 = 4.58		
					Mean vertical deviation from center of impact. 5'.61 Mean horizontal deviation from center of impact ...... 4'.58 Mean deviation from center of impact 7'.25								
From rear and right, 45°. 10 miles an hour.	*	*	20,700	*	Fired at 3,000-yard target; sighting shot; under target.								A crack was developed in the cast-iron casing extending longitudinally from a point 6 inches in front of the third loading hole to a point 12 inches in rear of the first loading hole, as per sketch accompanying. From the thirty-fourth round impressions were taken after each round, and it was shown that the crack in the steel tube, while scored by the powder gases, was extended in length only about 1¼ inches.

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* Not taken.

Star gauging of 6-inch multicharge gun.

Inches from muzzle.	Sept. 4, 1883. Original diameter of bore.	Sept. 7, 1883. Diameter of bore after 6 rounds.	Oct. 31, 1883. Diameter of bore after 31 rounds.	Dec. 9, 1884. (*)	Inches from muzzle.	Sept. 4, 1883. Original diameter of bore	Sept. 7, 1883. Diameter of bore after 6 rounds.	Oct. 31, 1883. Diameter of bore after 31 rounds.	Dec. 9, 1884. (*)
258 Shot chamber.	6.188	6.188	6.187	...	186	6.014	6.015	6.024	...
257	6.187	6.188	6.188	...	185	6.015	6.016	6.024	...
256	6.187	6.188	6.188	...	184	6.015	6.016	6.024	...
255	6.188	6.188	6.188	...	183	6.015	6.016	6.024	...
254	6.187	6.187	6.189	...	182	6.015	6.016	6.023	...
253	6.187	6.187	6.190	...	181	6.015	6.015	6.023	...
252	6.187	6.188	6.190	...	180	6.016	6.017	6.023	...
251	6.188	6.188	6.190	...	179	6.016	6.015	6.023	...
250	6.077	...	...	...	178	6.015	6.015	6.022	...
249	6.012	6.017	6.016	...	177	6.015	6.015	6.020	...
248	6.012	6.015	6.015	...	176	6.014	6.015	6.020	...
247	6.013	6.015	6.015	...	175	6.014	6.014	6.018	...
246	6.013	6.015	6.015	...	174	6.014	6.014	6.019	...
245	6.013	6.016	6.015	...	173	6.014	6.014	6.018	...
244	6.013	6.016	6.015	...	172	6.014	6.014	6.018	...
243	6.013	6.016	6.015	...	171	6.014	6.014	6.018	...
242	6.013	6.016	6.014	...	170	6.014	6.014	6.018	...
241	6.013	6.016	6.014	...	169	6.013	6.015	6.018	...
240	6.014	6.016	6.014	...	168	6.014	6.015	6.016	...
239	6.014	6.016	6.014	...	167	6.014	6.015	6.016	...
238	6.014	6.015	6.014	...	166	6.013	6.014	...	...
237	6.014	6.015	6.014	...	165	6.014	6.014	...	...
236	6.014	6.015	6.014	...	164	6.014	6.014	...	...
235	6.014	6.015	6.014	...	163	6.014	Pocket..	...	...
234	6.013	6.015	6.014	...	162	6.015	6.014	...	...
233	6.013	6.015	6.013	...	161	6.015	6.014	6.021	...
232	6.013	6.015	6.013	...	160	6.015	6.015	6.024	...
231	6.013	6.015	6.013	...	159	6.015	6.014	6.024	...
230	6.013	6.015	6.013	...	158	6.015	6.014	6.024	...
229	6.013	6.015	6.012	...	157	6.014	6.013	6.023	...
228	Pocket	6.015	6.013	...	156	6.014	6.013	6.023	...
227	Pocket..	6.016	6.016	...	155	6.014	6.013	6.023	...
226	Pocket..	Pocket.	...	...	154	6.014	6.013	6.022	...
225	Pocket.	6.015	...	...	153	6.014	6.013	6.022	...
224	Pocket.	6.015	...	...	152	6.014	6.014	6.023	...
223	6.013	6.015	6.020	...	151	6.014	6.014	6.023	...
222	6.013	6.015	6.023	...	150	6.015	6.014	6.024	...
221	6.013	6.014	6.026	...	149	6.015	6.015	6.023	...
220	6.013	6.014	6.026	...	148	6.017	6.017	6.024	...
219	6.013	6.014	6.024	...	147	6.017	6.017	6.024	...
218	6.013	6.014	6.022	...	146	6.017	6.017	6.024	...
217	6.013	6.014	6.020	...	145	6.017	6.016	6.022	...
216	6.013	6.014	6.020	...	144	6.016	6.016	6.021	...
215	6.013	6.014	6.020	...	143	6.016	6.015	6.020	...
214	6.013	6.014	6.020	...	142	6.016	6.015	6.019	...
213	6.012	6.014	6.020	...	141	6.014	6.014	6.017	...
212	6.012	6.014	6.020	...	140	6.014	6.014	6.017	...
211	6.012	6.014	6.019	...	139	6.014	6.014	6.016	...
210	6.012	6.015	6.019	...	138	6.014	6.014	6.016	...
209	6.012	6.014	6.019	...	137	6.014	6.014	6.015	...
208	6.013	6.014	6.019	...	136	6.014	6.014	6.014	...
207	6.013	6.014	6.019	...	135	6.014	6.014	6.013	...
206	6.014	6.014	6.019	...	134	Pocket..	Pocket..	6.013	...
205	6.014	6.013	6.018	...	133	Pocket..	Pocket..	...	...
204	6.014	6.013	6.018	...	132	Pocket	Pocket..	...	...
203	6.014	6.013	6.018	...	131	Pocket..	Pocket..	...	...
202	6.014	6.013	6.018	...	130	Pocket..	Pocket..	...	...
201	6.014	6.013	6.016	...	129	6.013	6.015	6.020	...
200	6.014	6.014	6.015	...	128	6.013	6.015	6.020	...
199	6.014	6.014	6.015	...	127	6.013	6.015	6.020	...
198	6.014	6.014	6.015	...	126	6.013	6.014	6.020	...
197	6.014	Pocket..	6.014	...	125	6.013	6.014	6.019	...
196	Pocket..	Pocket..	6.018	...	124	6.013	6.015	6.018	...
195	Pocket..	Pocket..	6.018	...	123	6.014	6.015	6.019	...
194	Pocket..	Pocket..	6.023	...	122	6.014	6.016	6.018	...
193	Pocket..	Pocket..	6.026	...	121	6.014	6.015	6.019	...
192	6.013	6.014	6.029	...	120	6.014	6.015	6.019	6.019
191	6.013	6.014	6.030	...	119	6.014	6.015	6.020	6.020
190	6.013	6.014	6.030	...	118	6.014	6.015	6.020	6.020
189	6.013	6.015	6.026	...	117	6.014	6.014	6.019	[illegible]
188	6.013	6.015	6.025	...	116	6.013	6.014	6.022	6.020
187	6.013	6.015	6.025	...	115	6.013	6.014	6.023	6.024

* Star gauged after three bands had been shrunk on, to ascertain if shrinkage of bands had changed bore, &c.

Star gauging of 6-*inch multicharge gun*—Continued.

Inches from muzzle.	Sept. 4, 1883. Original diameter of bore.	Sept. 7, 1883. Diameter of bore after 6 rounds.	Oct. 31, 1883. Diameter of bore after 31 rounds.	Dec. 9, 1884. (*)	Inches from muzzle.	Sept. 4, 1883. Original diameter of bore.	Sept. 7, 1883. Diameter of bore after 6 rounds.	Oct. 31, 1883. Diameter of bore after 31 rounds.	Dec. 9, 1884. (*)
114	6.012	6.014	6.023	6.024	56	6.010	6.010	6.014	6.016
113	6.010	6.013	6.023	6.024	55	6.010	6.011	6.014	6.016
112	6.010	6.012	6.022	6.024	54	6.010	6.010	6.014	6.016
111	6.010	6.011	6.021	6.025	53	6.010	6.010	6.013	6.016
110	6.010	6.011	6.021	6.025	52	6.010	6.010	6.013	6.016
109	6.010	6.011	6.021	6.025	51	6.009	6.010	6.012	6.015
108	6.010	6.011	6.021	6.025	50	6.009	6.010	6.011	6.014
107	6.010	6.011	6.020	6.025	49	6.009	6.009	6.011	6.014
106	6.010	6.011	6.020	6.025	48	6.009	6.009	6.011	6.014
105	6.010	6.012	6.021	6.025	47	6.009	6.009	6.010	6.014
104	6.010	6.013	6.020	6.025	46	6.009	6.008	6.010	6.014
103	6.011	6.013	6.020	6.024	45	6.008	6.008	6.010	6.014
102	6.011	6.013	6.020	6.024	44	6.008	6.008	6.010	6.014
101	6.011	6.014	6.020	6.023	43	6.008	6.008	6.010	6.014
100	6.011	6.013	6.020	6.023	42	6.008	6.007	6.010	6.014
99	6.011	6.013	6.020	6.023	41	6.007	6.007	6.010	6.014
98	6.011	6.013	6.020	6.023	40	6.006	6.007	6.010	6.013
97	6.010	6.012	6.019	6.022	39	6.006	6.006	6.009	6.013
96	6.010	6.011	6.018	6.020	38	6.006	6.006	6.008	6.013
95	6.010	6.011	6.017	6.020	37	6.005	6.005	6.008	6.014
94	6.009	6.010	6.017	6.020	36	6.005	6.005	6.008	6.015
93	6.009	6.010	6.017	6.020	35	6.004	6.004	6.007	6.015
92	6.009	6.010	6.017	6.020	34	6.004	6.004	6.007	6.015
91	6.009	6.010	6.016	6.020	33	6.003	6.004	6.006	6.015
90	6.010	6.010	6.016	6.021	32	6.003	6.003	6.006	6.015
89	6.010	6.011	6.016	6.022	31	6.003	6.003	6.006	6.015
88	6.010	6.015	6.019	6.025	30	6.003	6.003	6.006	6.016
87	6.016	6.016	6.022	6.026	29	6.003	6.003	6.006	6.016
86	6.016	6.017	6.022	6.026	28	6.003	6.003	6.006	6.017
85	6.015	6.016	6.020	6.025	27	6.003	6.003	6.006	6.016
84	6.015	6.015	6.020	6.025	26	6.002	6.002	6.005	6.016
83	6.015	6.016	6.020	6.025	25	6.001	6.002	6.005	6.016
82	6.014	6.016	6.019	6.025	24	6.001	6.002	6.005	6.016
81	6.014	6.015	6.020	6.025	23	6.000	6.001	6.005	6.015
80	6.013	6.015	6.020	6.024	22	6.000	6.001	6.004	6.015
79	6.013	6.015	6.018	6.024	21	6.000	6.001	6.004	6.014
78	6.013	6.015	6.018	6.024	20	6.000	6.000	6.004	6.014
77	6.013	6.014	6.019	6.023	19	6.000	6.000	6.004	6.013
76	6.013	6.014	6.018	6.023	18	6.000	6.000	6.003	6.013
75	6.013	6.014	6.018	6.023	17	6.000	6.000	6.003	6.012
74	6.013	6.015	6.019	6.023	16	6.000	6.000	6.003	6.010
73	6.013	6.014	6.018	6.023	15	6.000	6.000	6.003	6.010
72	6.013	6.014	6.018	6.023	14	6.000	6.000	6.003	6.009
71	6.013	6.014	6.018	6.023	13	6.000	6.000	6.003	6.009
70	6.013	6.014	6.018	6.022	12	6.000	6.000	6.003	6.008
69	6.013	6.013	6.017	6.022	11	6.000	6.000	6.003	6.008
68	6.013	6.014	6.017	6.021	10	6.000	6.000	6.003	6.008
67	6.012	6.013	6.016	6.021	9	6.000	6.000	6.004	6.008
66	6.011	6.013	6.015	6.020	8	6.000	6.000	6.004	6.007
65	6.011	6.012	6.016	6.020	7	6.000	6.000	6.004	6.006
64	6.011	6.011	6.015	6.020	6	6.000	6.000	6.004	6.006
63	6.010	6.011	6.015	6.019	5	6.002	6.001	6.007	6.007
62	6.010	6.011	6.015	6.017	4	6.003	6.002	6.007	6.007
61	6.010	6.011	6.015	6.017	3	6.004	6.003	6.008	6.007
60	6.010	6.010	6.014	6.017	2	6.005	6.004	6.009	6.007
59	6.010	6.010	6.014	6.016	1	6.007	6.007	6.012	6.010
58	6.010	6.010	6.015	6.019	Muzzle				6.023
57	6.010	6.011	6.016	6.019					

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* Star gauged after three bands had been shrunk on, to ascertain if shrinkage of bands had changed bore, &c.

Table showing calculated data for 6″ multicharge gun.

Date.	No. of round.	Weight of shot.	Weight of powder charge.	Velocities in feet per second at muzzle.	Total energy in foot-tons at muzzle.	Energy per square inch of shots' cross-section at muzzle.	Penetration in inches at muzzle.	Velocities in feet per second at 1,000 yards.	Total energy in foot-tons at 1,000 yards.	Energy per square inch of shots' cross-section at 1,000 yards.	Penetration in inches at 1,000 yards.
1884.		*Lbs.*	*Lbs.*			*Foot-tons.*				*Foot-tons.*	
Dec. 10	34	155	105	1,540	2,551.4	90.24	13.134	1,391	2,081.6	73.62	11.275
10	35	155	110	1,576	2,672.1	94.51	......	1,424	2,181.5	77.16	......
10	36	109	114	1,785	2,410.6	85.26	12.587	1,5 0	1,817.6	64.29	10.185
11	37	111	114	1,851	2,639.7	93.36	13.473	1,614	2,006.9	70.98	10.970
11	38	111	111	1,904	2,793.0	98.78	......	1,662	2,128.1	75.72	......
11	39	155	111	1,756	3,317.3	117.32	15.992	1,591	2,723.2	96.31	13.782
11	40	111	116	1,951	2,932.6	103.72	......	1,705	2,239.6	79.21	......
16	41	155	115	1,697	3,098.1	109.57	......	1,536	2,538.2	89.77	......
16	42	111	119	2,004	3,094.1	109.43	15.178	1,752	2,364.8	83.64	12.407
16	43	152	116	1,801	3,421.9	121.03	16.369	1,629	2,799.6	99.02	14.082
16	44	110	11	1,989	3,020.4	106.82	14.906	1,737	2,303.6	81.47	12.165
17	45	110	119	1,962	2,939.0	103.95	......	1,713	2,240.4	79.24	......
17	46	110	120	1,964	2,945.0	104.16	......	1,715	2,245.5	79.42	......
17	47	110	120	1,939	2,870.5	101.52	14.348	1,692	2,185.7	77.31	11.[illegible]
17	48	110	120	1,947	2,894.3	102.36	......	1,700	2,206.5	78.04	......
17	49	110	120	1,951	2,906.2	102.79	......	1,703	2,214.2	78.31	......
17	50	110	120	1,962	2,939.0	103.95	......	1,713	2,240.4	79.24	......
18	51	110	120	1,981	2,996.1	105.97	......	1,730	2,285.1	80.82	......
18	52	109	120	1,970	2,936.2	103.85	14.594	1,718	2,233.0	78.98	11.[illegible]
18	53	150	117	1,796	3,358.3	118.78	16.141	1,623	2,742.5	97.00	13.[illegible]

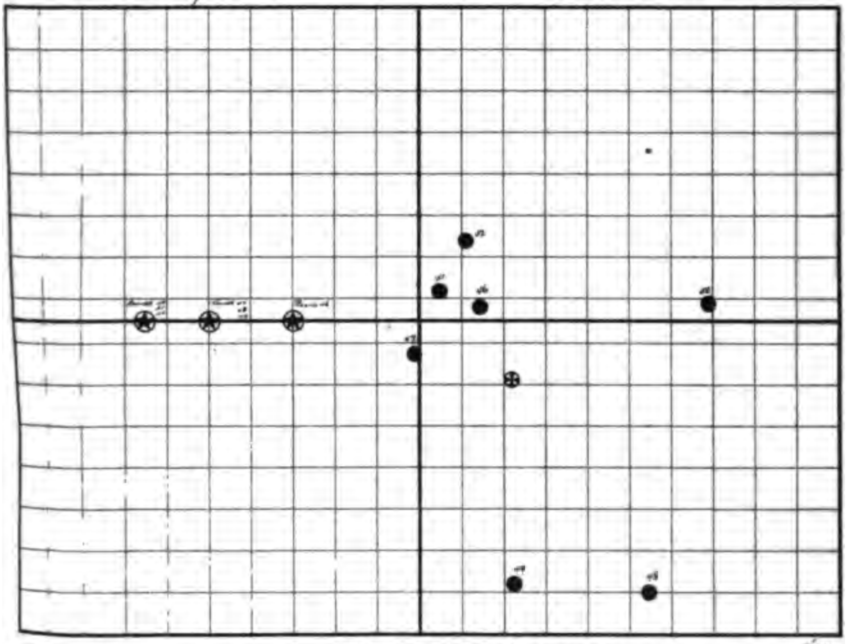
NOTE.—Penetrations calculated for greatest and least velocities obtained with each weight of projectile and by the Krupp formulæ, namely: $t = (0.0135\, r e^3)^{\frac{1}{3}}$.

TARGET RECORD of 6" Multicharge Gun

November 17th. '84 AT SANDY HOOK. N. J.

Target 3000 yards *from Gun.*

Number of shots fired, 7 . *Direct hits,* 7 . *Ricochet hits,* 0 . *Misses,* 0 .



● *Center of impact*

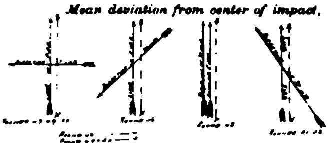
⊛ *Point aimed at*

Target 30 × 40

Mean vertical deviation from center of impact. 5'.61

Mean horizontal deviation from center of impact, 4'.58

Mean deviation from center of impact, 7'.25

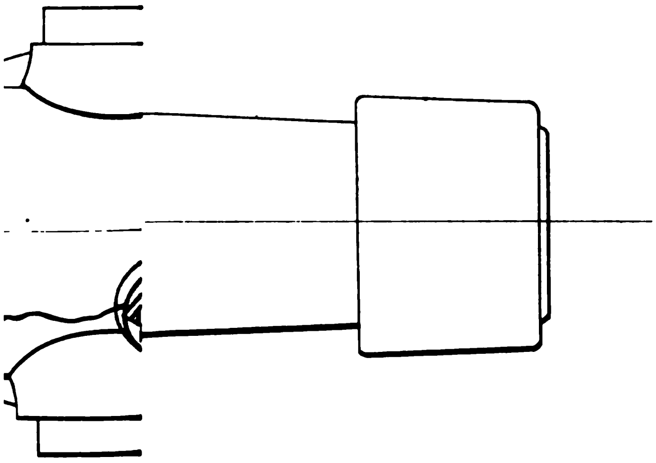


Wind } *miles per hour.*

H Ex1 pt2 v3 49 1

PLATE II.

URE



BOARD U.S.A.
RNORS ISLAND DECEMBER 29TH 1884.

APPENDIX 22.

ASSUMED AND CALCULATED DATA FOR CONSTRUCTING A 5-INCH STEEL SIEGE-GUN. BY THE ORDNANCE BOARD.

(1 plate.)

Assumed data.

Weight of projectile	pounds..	45
Weight of charge	do....	12
Density of loading		32
Length of chamber	inches..	15
Volume of chamber	cubic inches..	384
Length of bore	caliber (150 inches)..	30
Diameter of bore	inches..	5
Length of gun	do....	162
Weight of gun	pounds..	3,500
Preponderance at 1 foot from base of breech	do..	200

Physical properties.

	Tenacity.	Elastic limit.
	Pounds.	*Pounds.*
Jacket	95,000	45,000
Tube	80,000	38,000

Factor of safety		4
Factor of effect	per cent..	75

Calculated data.

(1) **Initial velocity**	feet..	17.10
(2) **Maximum pressure**	tons per square inch..	15.51
(3) **Distance of projectile from bottom of bore when maximum pressure exists, inches**		18.0

(4 *and* 5) *Pressures and velocities at different points of bore.*

Distance from front end of chamber.	Pressure in tons per square inch.	Velocities.	Difference.
Inches.		*Feet.*	*Feet.*
3	15.51	559.8	....
5	13.75	696.6	....
15	8.64	1035.4	338.8
25	6.24	1202.8	167.4
35	4.88	1311.3	108.5
45	4.00	1390.6	79.3
55	3.38	1452.5	61.9
65	2.93	1503.0	50.5
75	2.60	1545.3	42.3
85	2.34	1581.6	36.3
95	2.15	1613.4	31.8
105	1.97	1641.6	28.2
115	1.80	1666.7	25.1
125	1.65	1689.5	22.8
135	1.53	1710.3	20.8
			Muzzle

(6) Thickness of wall at maximum diameter of chamber with factors of safety	4
Thickness of tube ... inches	1.7
Thickness of jacket ... do	2.8
	4.5
(7) Elastic resistance of chamber ... tons	15.636
Elastic limit of tube assumed ... pounds	38,000
(8) Jacket may terminate in front of face of chamber ... inches	36
(9) Shrinkage per linear inch	0.0014
Total shrinkage	0.01274
(10) Initial compression of tube under shrinkage ... tons per square inch	4.036
Resistance of tube to compression ... tons per square inch	6.185

Comparative table of foreign siege guns of about 12^{cm}

Nation or manufacture.	Denomination.	Material.	Caliber, inches.	Weight, pounds.	Preponderance, pounds.
Krupp	10.5^{cm}	Steel hooped	4.13	2,590.4	264.
France	DeBange 12^{cm}	Steel hooped	4.72	2,645.5	—43.
Italy	Plastic obturator	Steel hooped	4.70	3,086.	at 3'.28 220.
Austria	12^{cm}	Compressed bronze	4.7	3,740.	187.4
Swiss	12^{cm}	Steel	4.7	3,124.	390.
England	40-pdr., 35 cwt., M. L	Steel, wrought iron	4.75	3,864.	24.
Projected (United States)	5-inch	Steel jacketed	5.	3,500.	200.

Comparative table of foreign siege guns of about 12^{cm} (4".7)

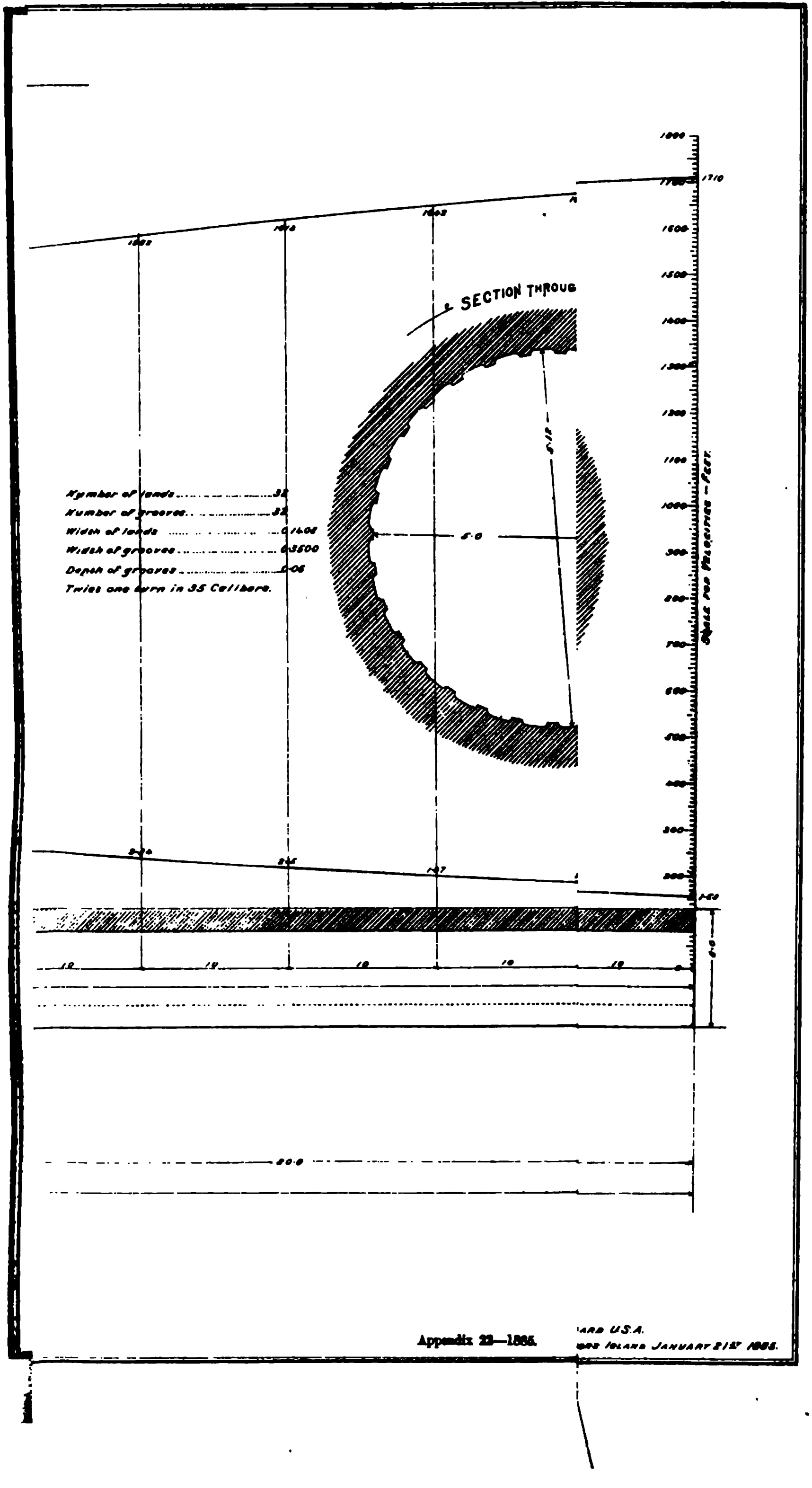
Nation or manufacture.	Denomination.	Material.	Powder charge.	
			Weight, pounds.	Nature of grains.
Krupp	10.5^{cm}	Steel hooped	8.16	Prismatic density 1.64.
France	DeBange 12^{cm}	Steel hooped	9.93	
Italy	Plastic obturator	Steel hooped	9.9	
Austria	12^{cm}	Compressed bronze	10.58	Grains 0.5" thick
Swiss	12^{cm}	Steel	7.	Prismatic Rottweil
England	40-pdr., 35 cwt., M. L	Steel, wrought iron	7.	R. L. G
Projected (United States)	5 inch	Steel jacketed	12.	

(4".7) caliber and proposed 5*-inch steel siege gun.*

Length.			Twist.		Grooved.			Powder chamber.	
	Bore.								
Total, inches.	Inches.	Caliber.	Feet.	Caliber.	Width, inches.	Depth, inches.	Number.	Length, inches.	Diameter, inches.
144.8	133.07	32.2	....	....	0.268	0.1378	32	....	4.92
127.95	117.	24.75	Increasing. 1° 30′ to 7°		0 315	0.03	36	21.65	4.88
} 110.59	104.	22.04	Uniform. 19.66	50	....	0.063	36	14.04	5.00
128.	116.14	22.5	Increasing. 0 to 4°		0.35	0.059	30	18.7	4.9
115.1	102.4	21.7	Uniform. 17.71	45	0.326	0.059	32	....	....
120.	104.5	22.	13.85	35	0.8	0.10	3	No chamber.	
162.	150.	30.	14.58	35	0.35	0.06	32	15.	5.7

caliber and proposed 5*-inch steel siege gun*—Continued.

Projectile.			Initial velocity, foot-seconds.	Pressure per square inch, pounds.	Muzzle energy.					Velocity at—				
Length, caliber.	Weight, pounds.	Bursting charge, pounds.			Total, foot-tons.	Inch of circumference, foot-tons.	Inch of cross-section, foot-tons.	Pound of powder, foot-tons.	Pound weight of gun, foot-pounds.	1,000 yards, foot-seconds.	2,000 yards, foot-seconds.	3,000 yards, foot-seconds.	4,000 yards, foot-seconds.	5,000 yards, foot-seconds.
2.8 to 4. }	35.27	1.52	1,558.	34,125	594.2	45.80	44.36	72.8	502.2	1,263.	1,056.	945.5	857.	783.5
2.92	30.24	1.76	1,575.4	....	677.5	45.69	38.71	68.30	573.6	1,233.	1,019.	901.5	808.5	730.
2.83	36.37	2.2	1,666.	....	700.7	47.45	40.39	70.77	508.6	1,280.	1,031.5	904.	804.5	721.
1.97	36.81	2.	1,693.7	24,463	732.9	49.64	42.24	69.27	429.	1,305.	1,045.	915.	814.5	731.
.....	36.9	2.46	1,558.	....	621.7	42.11	35.83	88.81	445.8	1,205.	999.	880.5	786.8	706.8
2.85	29.62	2.5	1,425.	....	558.4	37.42	31.51	79.77	323.7	1,127.5	967.5	861.	774.6	700.
3.	45.	2.23	1,710.	34,742	913.3	58.14	46.52	76.10	604.38	1,343	1,080.5	945.6	845.5	763.5


SECTION THROUG
Number of lands 32
Number of grooves 32
Width of lands 0.1408
Width of grooves 0.3500
Depth of grooves 0.06
Twist one turn in 35 Calibers.
5·0
1800
1710
1700
1600
1500
1400
1300
1200
1100
1000
900
800
700
600
500
400
300
200
SCALE FOR VELOCITIES — FEET.
10
10
10
10
10
6·0
20·0
ARD U.S.A.
ORS ISLAND JANUARY 21ST 1885.

Appendix 23—1885.

APPENDIX 23.

CONSTRUCTION REPORT OF THE CAST-IRON BODY FOR THE TEN-INCH WIRE-WRAPPED B. L. RIFLE.

BY CAPT. D. A. LYLE, ORDNANCE DEPARTMENT, U. S. A.

TIME EMPLOYED.

This body was included in the contract made September 24, 1883, with the South Boston Iron Works. It was cast March 28, 1884, and was inspected August 28–29, 1884. The body was finished in five months from the date of casting and within eleven months of the date of the contract.

THE CASTING.

The details regarding the furnace charges, the record of casting, the cooling, the physical properties, and the initial tension are given in the statement of fabrication appended hereto and forming part of this report.

The casting was made breech down, with an excess of metal upon the breech sufficient to allow a cylinder about fifteen inches in length to be taken from that end for experimental purposes.

FINISHING.

The chase of this gun was finish-turned. The cylindrical portions designed to receive the wire wrapping was ordered to be turned to the dimensions given in the drawing, but when completed it was found that these diameters exceeded those prescribed by about .04 inch.

This variation was subsequently authorized. The rifled portion of the bore was directed to be bored out to 9.95 inches, leaving .05 inch. for finish-boring after wrapping with wire.

The same allowance was made in the diameter of the chamber, leaving it to be finished after the application of the wire, and to have the seat for the steel bushing of the breech-block cut in the rear end. The forward slope of the chamber was also left to be finished after the wrapping with wire.

A slight excess of metal was left at the breech end to serve for starting reamers and boring tools.

PHYSICAL PROPERTIES.

The prescribed tenacity was required to be not less than 30,000 nor more than 37,000 pounds per square inch. The usual tenacity specimens, taken from both ends of the casting, all fell within these limits. The initial tension was as follows: Muzzle, 16,190 pounds per square inch; breech, 13,125 pounds per square inch.

SHIPMENT.

The body for the 10-inch wire-wrapped B. L rifle was shipped to the commanding officer of Watertown Arsenal, November 12, 1884.

REMARKS.

Attached to this report will be found star gauge record of measurements of the bore and measurements of the exterior diameters of the gun body, together with the variations in the exterior diameters.

TABLE I.—*Statement of fabrication of ordnance for the service of the United States by South Boston Iron Works, at the South Boston Foundry, under the supervision of Capt. D. A. Lyle, Ordnance Department.*

[Cast-iron body for 10-inch wire-wrapped B. L. R. gun. Cast March 28, 1884. Inspected August 28–29, 1884.]

CHARGE.

Iron used.

Grade of iron.	Furnaces.			
	No. 1.	No. 2.	No. 3.	Total.
	Tons.	*Tons.*		*Tons.*
No. 1				
No. 2	6	6	Richmond iron	12
No. 3, hard*	6	6		12
No. 3, soft	6	6		12
Remelted	9	9	Sections of 15-inch Rodman S. B. guns.	18
	27	27		54

* Classed as No. 4 Richmond at this foundry.

Coal consumed: Not kept accurately. Approximately 27 tons.
Character of test sticks: Record not kept.

RECORD OF CASTING.

Furnaces fired March 28, No. 1 at 4 a. m., No. 2 at 3.30 a. m.
Metal down at 11.30 a. m.
Time of melting: No. 1, 7½ hours; No. 2, 8 hours.
Time in fusion, 4⅙ hours.
Gun cast at 3.40 p. m.
Time occupied in casting, 11 minutes.
Temperature of water entering core-barrel, 39 degrees.
Temperature of water leaving core-barrel, 39 degrees.
Rate of water per minute, 36 gallons.
Fire kindled in pit about 4 p. m.
Fire in pit went out March 29, about 3 p. m.
Fire in pit burned about 23 hours.
Water shut off March 29 at 9 a. m.
Core-barrel removed at 11 a. m.
Water entered gun at 12 m.
Rate of water per minute, 20 gallons.
Temperature of water entering gun, 39 degrees.
Temperature of water leaving gun, 172 degrees.
Total time in cooling gun, 90½ hours.

COOLING TABLES.

Core-barrel.				Core-barrel removed.													
Hours.	Degrees.	Hours.	Degrees.	Hours.	Degrees.	Hours.	Degrees.	Hours.	Degrees.	Hours.	Degrees.	Hours.	Degrees.	Hours.	Degrees.	Hours.	Degrees.
*1	70	12	62	23	165	34	98	45	58	56	48	67	43.5	78	41	89	40
2	78	13	60	24	162	35	95	46	56	57	48	68	43	79	41	90	40
3	72	44	60	25	156	36	91	47	53	58	48	69	42.5	80	41	91	‖40
4	70	15	60	26	152	37	86	48	51	59	47	70	42.5	81	41	....	......
5	68	16	60	27	146	38	82	49	51	60	47	71	42	82	40.5	....	......
6	66	17	60	28	141	39	78	50	51	61	46	72	42	83	40.5	....	......
7	66	18	59	29	135	40	72	51	50	62	46	73	42	84	40.5	....	......
8	66	19	(†)	30	128	41	68	52	50	63	44	74	42	85	40.5	....	......
9	64	20	(‡)	31	120	42	64	53	49	64	44	75	42	86	40.5	....	......
10	64	21	§172	32	112	43	61	54	49	65	44	76	42	87	40.5	....	......
11	62	22	168	33	106	44	60	55	49	66	43.5	77	42	88	40.5	....	......

* Rate of water, 36 gallons per minute.
† Water off.
‡ Barrel removed.
§ Rate of water, 20 gallons per minute.
‖ Water shut off and began opening flask.

MECHANICAL TESTS.

Specific gravity.

Breech ring.			Muzzle ring.	
Specimen.	How taken.	Density.	How taken.	Density.
No. 1—I	Tangentially	7.2889	Tangentially	7.2942
No. 2—M	do	7.2811	do	7.2849
No. 3—O	do	7.2804	do	7.2819
No. 12—O	Longitudinally	7.2787	Longitudinally	7.2805
No. 13—M	do	7.2854	do	7.2776
No. 14—I	do	7.2756	do	7.2717
No. 15—I	do	7.2875		
No. 16—O	do	7.2716		
No. 17—O	do	7.2703		

TENSILE STRENGTH.

Breech ring.		Muzzle ring.	
Specimen.	Tenacity.	How taken.	Tenacity.
No. 1—I	34,749	Tangentially	32,947
No. 2—M	32,361	do	30,163
No. 3—O	32,715	do	30,024
No. 12—O	31,301	Longitudinally	32,716
No. 13—M	32,770	do	31,831
No. 14—I	33,268	do	32,273
No. 15—I	32,701		
No. 16—O	34,301		
No. 17—O	31,791		

INITIAL TENSION.

	Exterior diameter of ring.	Thickness of broken section.	Exterior opening.	Extension per inch of circumference.	Initial tension.
	Inches.	*Inch.*	*Inch.*	*Inch.*	
Breech	31.026	....	.061	.00061158	13,125
Muzzle	34.125	0.247	.101	.00094	16,190

REMARKS.—The entire operation and superintendence of and responsibility for the casting were under the direction of the founders, and the only supervision exercised by the inspectors was that required by the contract, so far as it provides for inspection at every stage of the manufacture.

TABLE II.—*Star gauging of bore of 10-inch wire wrapped B. L. rifle, as finished by the South Boston Iron Works.*

[Finished diameter of bore = 10 inches. Prescribed diameter of bore = 9.95 inches.]

Inches from muzzle.	Horizontal.	Vertical.	Inches from muzzle.	Horizontal.	Vertical.	Inches from muzzle.	Horizontal.	Vertical.	Inches from muzzle.	Horizontal.	Vertical.
1	......	......	115	9.950	9.950	189	9.949	9.949	245	10.810	10.813
3	......	......	117	9.949	9.950	190	9.949	9.949	246	10.810	10.810
5	9.950	9.951	119	9.949	9.951	191	9.949	9.949	247	10.810	10.811
7	9.949	9.950	121	9.950	9.951	192	9.949	9.949	248	10.810	10.810
9	9.949	9.950	123	9.950	9.950	193	9.949	9.949	249	10.810	10.813
11	9.949	9.951	125	9.949	9.951	194	9.949	9.949	250	10.808	10.810
13	9.950	9.951	127	9.949	9.950	195	9.948	9.949	251	10.808	10.810
15	9.951	9.951	129	9.949	9.950	196	9.948	9.949	252	10.809	10.809
17	9.949	9.951	131	9.949	9.951	197	9.948	9.949	253	10.808	10.812
19	9.950	9 951	133	9.949	9.951	198	9.948	9.919	254	10.808	10.810
21	9.950	9.951	135	9.949	9.950	199	9.949	9.949	255	10.810	10.809
23	9.950	9.951	137	9.949	9.950	200	9.949	9.949	256	10.811	10.813
25	9.950	9.951	139	9.949	9.951	201	9.949	9.949	257	10.812	10.815
27	9.950	9.951	141	9.949	9.951	202	9.919	9.949	258	10.810	10.811
29	9.950	9.951	143	9.949	9.951	203	9.949	9.949	259	10.810	10.811
31	9.950	9.950	145	9.949	9.949	204	9.949	9.949	260	10.806	10.804
33	9.950	9.950	147	9.949	9.950	205	9.948	9.919	261	10.8025	10.805
35	9.950	9.950	149	9.949	9.950	206	9.948	9.949	262	10.803	10.805
37	9.949	9.950	150	9.949	9.950	207	9.948	9.949	263	10.804	10.804
39	9.949	9.950	151	9.949	9.950	208	9.949	9.949	264	10.804	10.806
41	9.949	9.950	152	9.949	9.950	209	9.948	9,949	265	10.806	10.808
43	9.949	9.950	153	9.949	9.950	210	9.947	9.949	266	10.806	10.808
45	9.949	9.950	154	9.949	9.950	211	9.948	9.949	267	10.806	10.807
47	9.950	9.950	155	9.949	9.950	212	9.948	9.949	268	10.803	10.805
49	9.950	9.950	156	9.949	9.950	213	9.948	9.949	269	10.803	10.805
51	9.949	9.950	157	9.949	9.949	214	9.948	9.949	270	10.803	10.805
53	9.950	9.950	158	9.949	9.949	215	9.948	9.949	271	10.803	10.804
55	9.949	9.950	159	9.949	9.950	216	9.948	9.949	272	10.803	10.804
57	9.949	9.950	160	9.949	9.950	217	9.948	9.949	273	10.806	10.807
59	9.950	9.950	161	9.949	9.950	218	9.948	9.949	274	10.806	10.806
61	9.950	9.950	162	9.949	9.950	219	9.948	9.949	275	10.804	10.804
63	9.950	9.950	163	9.949	9.950	220	9.948	9.949	276	10 803	10.804
65	9.949	9.950	164	9.949	9.950	221	9.948	9.945	277	10.803	10.804
67	9.950	9.950	165	9.949	9.949	222	9.948	9.949	278	10.803	10.804
69	9.950	9.950	166	9.948	9.949	223	9.947	9.949	279	10.803	10.804
71	9.950	9.950	167	9.948	9.950	224	9.948	9.948	280	10.802	10.806
73	9.949	9.950	168	9.948	9.950	225	9.947	9.948	281	10 802	10.803
75	9.950	9.950	169	9.949	9.950	226	Front end of chamber.	Not measured.	282	10.802	10.803
77	9.950	9.950	170	9.949	9.950	227			283	10.801	10.803
79	9.950	9 950	171	9.949	9.950	228			284	10.803	10.803
81	9.950	9.950	172	9.949	9.949	229			285	10.803	10.803
83	9.950	9.950	173	9.949	9.949	230			286	10.802	10.803
85	9.949	9.950	174	9.948	9.949	231			287	10.803	10.803
87	9.950	9.950	175	9.948	9.949	232			288	10.802	10.802
89	9.950	9.950	176	9.949	9.949	233			289	10.801	10.806
91	9.950	9.950	177	9.948	9.949	234			290	10.803	10.802
93	9.950	9.949	178	9.949	9.949	234.1	9.792	9.746	291	10.803	10.802
95	9.950	9.950	179	9.749	9.949	235	10.810	10.836	292	10.799	10.802
97	9.949	9.950	180	9.949	9.949	236	10.813	10.813	293	10.800	10.801
99	9.949	9.950	181	9.949	9.949	237	10.813	10.816	294	10.799	10 801
101	9.949	9.950	182	9.948	9.949	238	10.811	10.816	295	10.800	10.801
103	9.949	9.950	183	9.948	9.949	239	10.812	10.812	296	10.800	10.802
105	9.949	9.950	184	9.947	9.949	240	10.809	10.812	297	10.800	10.803
107	9.949	9.950	185	9.949	9.949	241	10.812	10.812	298	10.801	10.802
109	9.950	9.950	186	9.948	9.949	242	10.811	10.812	299	10.801	10.806
111	9.949	9.950	187	9.918	9.949	243	10.811	10.812	300	10.802	10.807
113	9.949	9.950	188	9.949	9.949	244	10.810	10.813			

TABLE III.—*Caliper record of exterior of cast-iron body of* 10-*inch wire-wrapped breech-loading rifle.*

DIAMETERS.

Inches from muzzle.	Prescribed dimensions.	Actual.		Allowed variation.	Actual variation.*	Eccentricity.†
		Horizontal.	Vertical.			
....	19	19.115	19.100	±.025	+.115	.015
72	....	23.312	23.308	....	....	.004
116.75	26	25.988	25.980	±.025	-.012	.008
126.75	....	26.930	26.920	....	....	.01
136.75	....	27.986	27.987	....	....	.001
146.75	....	29.341	29.339	....	....	.002
154.75	30.5	30.508	30.505	±.025	+.008	.003
156	31.25	31.395	31.286	+.03	+.145	.109
157	31.25	31.395	....	+.03	+.145	....
158	31.25	31.300	31.295	+.03	+.05	.005
159	31.25	31.285	....	+.03	+.035	....
160	31.25	31.290	31.292	+.03	+.04	.002
161	31.25	31.287	....	+.03	+.037	....
162	31.25	31.291	31.288	+.03	+.041	.003
163	31.25	31.292	....	+.03	+.042	....
164	31.25	31.287	31.285	+.03	+.037	.002
165	31.25	31.286	....	+.03	+.036	....
166.75	31.25	31.285	31.289	+.03	+.035	.004
167	28	28.023	28.032	+.04	+.023	.009
169	28	28.040	28.045	+.04	+.040	.005
171	28	28.046	28.059	+.04	+.046	.013
173	28	28.048	28.051	+.04	+.048	.003
175	28	28.0461	28.060	+.04	+.0461	.0139
177	28	28.0472	28.071	+.04	+.0472	.0238
179	28	28.0473	28.064	+.04	+.0473	.0167
181	28	28.051	28.059	+.04	+.051	.008
183	28	28.0502	28.058	+.04	+.0502	.0078
185	28	28.0495	28.065	+.04	+.0495	.0155
187	28	28.046	28.051	+.04	+.046	.005
189	28	28.0464	28.051	+.04	+.0464	.0046
191	28	28.0458	28.053	+.04	+.0458	.0072
193	28	28.0465	28.059	+.04	+.0465	.0125
195	28	28.0488	28.057	+.04	+.0488	.0082
197	28	28.0508	28.054	+.04	+.0508	.0032
199	28	28.051	28.057	+.04	+.051	.006
201	28	28.0528	28.059	+.04	+.0528	.0062
203	28	28.0538	28.061	+.04	+.0538	.0072
205	28	28.0544	28.055	+.04	+.0544	.0006
207	28	28.054	28.059	+.04	+.054	.005
209	28	28.0529	28.068	+.04	+.0529	.0121
211	28	28.0508	28.072	+.04	+.0508	.0212
213	28	28.0518	28.072	+.04	+.0518	.0212
215	28	28.0533	28.071	+.04	+.0533	.0177
217	28	28.0545	28.065	+.04	+.0545	.0105
218.75	28	28.0375	28.050	+.04	+.0375	.0125
219	29.7	29.7875	29	+.04	+.0875	....
220	29.7	29.7882	29.8	+.04	+.0882	.0118
223	29.7	29.7882	29.798	+.04	+.0882	.0098
225	29.7	29.7875	29.790	+.04	+.0875	.0025
227	29.7	29.7876	29.795	+.04	+.0876	.0074
229	29.7	29.7876	29.789	+.04	+.0876	.0014
231	29.7	29.7876	29.787	+.04	+.0876	.0006
233	29.7	29.788	29.795	+.04	+.088	.007
235	29.7	29.7875	29.795	+.04	+.0875	.0075
237	29.7	29.788	29.796	+.04	+.088	.008
239	29.7	29.788	29.792	+.04	+.088	.004
241	29.7	29.7884	29.791	+.04	+.0884	.0026
243	29.7	29.7883	29.793	+.04	+.0883	.0047
245	29.7	29.7876	29.792	+.04	+.0876	.0044
247	29.7	29.7872	29.795	+.04	+.0872	.0078
249	29.7	29.7865	29.791	+.04	+.0865	.0045
251	29.7	29.7858	29.790	+.04	+.0858	.0042
253	29.7	29.7855	29.789	+.04	+.0855	.0035
255	29.7	29.7868	29.791	+.04	+.0868	.0042
257	29.7	29.787	29.796	+.04	+.087	.009
259	29.7	29.7879	29.796	+.04	+.0879	.0081
261	29.7	29.7875	29.790	+.04	+.0875	.0025

*Obtained by taking the difference between the "prescribed dimensions" and actual horizontal dimensions

†Difference between the horizontal and vertical diameters.

TABLE III.—*Caliper record of exterior of cast-iron body of* 10-*inch wire-wrapped breech-loading rifle*—Continued.

DIAMETERS.

Inches from muzzle.	Prescribed dimensions.	Actual.		Allowed variation.	Actual variation.*	Eccentricity.†
		Horizontal.	Vertical.			
263	29.7	29.7888	29.791	+.04	+.0888	.0022
264	29.7	29.7868	29.800	+.04	+.0868	.0132
266	29.7	29.7873	29.805	+.04	+.0873	.0177
268	29.7	29.7881	29.845	+.04	+.0881	.0569
270	29.7	29.7883	29.830	+.04	+.0883	.0417
272	29.7	29.7888	29.792	+.04	+.0888	.0032
274	29.7	29.7888	29.821	+.04	+.0888	.0322
276	29.7	29.7896	29.820	+.04	+.0896	.0304
278	29.7	29.7898	29.796	+.04	+.0898	.0062
280	29.7	29.790	29.793	+.04	+.090	.003
282	29.7	29.7863	29.785	+.04	+.0863	.0013
284	29.7	29.7804	29.777	+.04	+.0804	.0034
286	29.7	29.7743	29.774	+.04	+.0743	.0003
287	29.7	29.7644	......	+.04	+.0644	....
288	29.7	29.7635		+.04	+.0635	....
289	29.7	29.7638		+.04	+.0638	....
290	29.6	29.7638		+.04	+.0638	....
291	29.7	29.7628		+.04	+.0628	....
292	29.7	29.7628		+.04	+.0628	....
293	29.7	29.7628		+.04	+.0628	....
294	29.7	29.7634		+.04	+.0634	....
295	29.7	29.7635		+.04	+.0635	....
296	29.7	29.7628		+.04	+.0628	....
297	29.7	29.763		+.04	+.063	....
298	29.7	29.759		+.04	+.059	....
299	29.7	29.7652		+.04	+.0652	....
300	29.7	29.7673	29.778	+.04	+.0673	.0107

*Obtained by taking the difference between the "prescribed dimensions" and actual horizontal dimensions.

†Difference between the horizontal and vertical diameters.

APPENDIX 24.

CONSTRUCTION REPORT OF THE 12-*INCH CAST-IRON BREECH-LOADING RIFLE FABRICATED BY THE SOUTH BOSTON IRON WORKS DURING THE YEARS* 1883–1885.

BY CAPT. D. A. LYLE, ORDNANCE DEPARTMENT, U. S. A.

(1 plate.)

TIME EMPLOYED.

This gun was contracted for September 24, 1883. It was cast on May 6, 1884, and was finished and ready for inspection April 1, 1885. The actual time required for fabrication was ten months and twenty-five days, and the total time between the date of the contract and the time of finishing the gun was eighteen months and seven days.

DESCRIPTION.

This breech-loading gun is made of cast-iron with a breech bushing of steel, and is provided with the interrupted screw fermeture. The exterior outline conforms closely to the Rodman model.

The steel for the breech-bushing, breech screw, spindle, and lever was made by the Midvale Steel Company, of Nicetown, Philadelphia, Pa. The console and hinge-plate are of bronze; the latches, hinge-pin, and smaller screws are made of wrought iron.

The dimensions of the gun and the details of the breech mechanism are given on the original drawings on file in the Ordnance Office.

PRINCIPAL DIMENSIONS.

Total length of gun	inches	360
Length of rifled portion of bore	do	273
Length of chamber	do	69
Length of breech bushing	do	18
Total length of bore	do	242
Diameter of bore	do	12
Chamber:		
Total length	do	71
Seat for base of shot (unfinished)	do	
Provisional length	do	2
Length conical part	do	0.5
Length cylindrical part	do	1.5
Diameter:		
Front of cone	do	12
Rear of cone	do	12.20
Cylindrical part	do	12.20
Powder space:		
Length of curved part	do	9
Length cylindrical part	do	57
Length of seat for gas check	do	3
Total length	do	69
Distance spindle projects into chamber	do	6.5
Length actual powder space	do	62.5

Exterior:		
Maximum diameter (over seat of charge)	inches	56
Diameter at muzzle	do	24
Diameter of cylindrical projection in rear	do	41
Length of cylindrical projection in rear	do	2.75
Trunnions:		
Length	do	7
Diameter	do	15
Rimbases:		
Diameter of	do	17
Distance between	do	55.035
Distance from axis of trunnions to muzzle	do	240.75
Preponderance (practically)	do	

PRINCIPAL WEIGHTS.

Total weight of gun complete (estimated)*	tons	54
Breech block	pounds	900
Breech bushing	do	1,195
Spindle, clamp, and bolts	do	195.5
Lever complete	do	101
Console	do	177
Total weight breech mechanism	do	2,720

RIFLING.

The rifling is polygroove, with an equal number of lands and grooves. The twist is first increasing and then uniform to the muzzle.

Details.

Grooves:		
Number of		60
Width	inches	0.4483
Depth	do	0.06
Width of lands	do	0.18
Radius of fillet-bottom of grooves	do	0.08
Lands rounded with radius of	do	0.01
Twist (increasing) 1 turn in 135 calibers at origin to 1 turn in 40 calibers, and uniform at 33 inches from muzzle for the remainder, and 1 turn in 40 calibers.		
Total length of rifled portion of bore	inches	273
Length of bore having increasing twist	do	240
Length of bore having uniform twist	do	33

VENTING.

The vent is axial and coincident with the axis of the spindle. A vent bushing is placed in the front end of the mushroom head of the spindle. This bushing is of copper, cylindrical, 1.5 inches in diameter and 1.5 inches in length, inserted into a counterbore in the mushroom head by pressure.

The bottom of this counterbore is finished with an annular dovetail, into which the copper is forced by pressure, thus locking the bushing in its seat. The diameter of the vent through the bushing is 0.1 inch; through the rest of the spindle, 0.2 inch. The copper bushing is finished flush with the face of the mushroom head.

MARKS.

The gun is marked upon the muzzle face as follows: "12-inch—S. B. I. W.—1885.—D. A. L.—Wt., 54 tons." The marking is placed in a circle concentric with the bore.

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* The South Boston Iron Works possessed no scales of sufficient capacity to weigh such a mass, therefore the weight was estimated.

POWDER PROOF.

The contract of September 24, 1883, provides that this 12-inch rifle "shall be subjected to a powder proof of five (5) rounds, each of 150 pounds of powder, with a projectile not exceeding 800 pounds in weight, prior to its final acceptance."

FABRICATION.

The casting.

The contract provided that the casting for this gun should "be made hollow, and be cooled from the interior by a current of air or water;" that the exterior at the same time should be "kept hot either by a fire built around the flask within the casting pit, or by filling the space between the flask and the pit-walls with some suitable non-conducting material;" that the gun should be cast breech up, with a sinking head not less than 7 feet long, and that the casting should be "sound, free from cavities, soft spots, and flaws."

It also provided that the cast-iron used should be charcoal pig of standard quality, prescribed by the Ordnance Department for the manufacture of heavy guns, and that specimens taken from the lower end of the sinking head should have "an ultimate tenacity of not less than 30,000 pounds nor more than 37,000 pounds per square inch." The casting was made with the larger or breech end up, with a riser of the full diameter about 7 feet long. The form of the casting was conoidal, without any swells or projections except the trunnions; consequently, the longitudinal shrinking of the metal during cooling was almost unimpeded by any extraneous condition of the mold or flask detrimental to the integrity of the casting.

The charges for the furnaces, together with all the details of the casting and cooling, will be found tabulated and appended to this report. The total charge as given by the founders was 108 tons, and the time of cooling 158¼ hours.

The physical properties of the metal were determined from a breech ring taken from the lower end of the sinking head directly contiguous to the breech. A second ring was taken later from the muzzle about 4 inches in front of the face. This was defective on one side, owing to the projection into the body of the ring of the wrought-iron chaplet used to center the core. This caused one of the long tangential specimens to be defective.

FINISHING.

In turning the exterior the prescribed diameters varied from +0″.09 to —0″.09, while the allowed variation is ±.″02. (See table of "exterior diameters of body," appended, marked "Table V," and the note at the end of that table.)

In turning the rimbases the workman cut into one of them for a short distance, making the distance between them less than it should be. The remainder of the rimbase was finished in accordance with the drawing.

In boring out the interior a portion of the bore from 69 inches to 75 inches, estimated from the muzzle, both inclusive, showed a variation in the vertical diameter of about 0″.01 above the prescribed variation.

The seat for the breech bushing and the exterior of the bushing were very accurately bored and turned, and an excellent contact was made at the front face and over the fillet. The rounded shoulder had no contact on the curve.

The breech mechanism was made to conform closely to the drawings.

To prevent too much wear on the hinge a steel plate or washer was inserted under the hinge of the console. The catches were finished in place. The handle of the translating screw would be more convenient and easier on the hand if it were movable on an arbor instead of being fixed as at present, and constrained to turn in the hand in manipulation. The crank or lever-arm of this handle would be better were it larger, in order to give more leverage. The curved slot in the bushing for the pinion of the vent-cover is too abrupt at its lowest point, and requires the operator to assist the cover over this point with his finger when the lever nears the extremity of its path to the right.

This defect has been remedied in drawings for future constructions.

The lock for the lever handle should have the spindle placed in the lever itself, beveled more on its striking-faces, else the handle cannot be rotated. The rear face of this handle, which strikes the spindle in the lever, should be faced with steel, or it will wear rapidly in service.

With the spring placed around the spindle in the handle, the "split nut" is unnecessary. If a weaker spring were used the nut might be a valuable adjunct to give an initial compression to the spring, or if the spring should set after use it will be advantageous. It is furnished with this gun, but will probably be removed in firing.

The breech mechanism after assembly worked well, except the vent-cover. The translating screw, when it was turned very slowly to withdraw the breech-block, appeared to bind when the nut was about six inches from the stop. When the screw was rotated rapidly this difficulty was not experienced. No attempt was made to change or remedy this, as it was thought best not to delay the completion of the gun, but to see if this defect would cause trouble in manipulation. If so, it could be determined whether the screw was too weak, and consequently would bend, or whether the binding proceeded from mechanical imperfections. The sections of the interrupted screw, both on the block and in the bushing, had the edges and corners all rounded.

The clearance for the shoulder of the spindle is .01 inch all around and around the spindle itself the clearance is .02 inches.

By an oversight the firing-lock or hammer was omitted and the gun shipped without it. It can be furnished if desired by the Department.

PHYSICAL PROPERTIES.

BREECH RING.

Mean tenacities and mean densities.

Specimens.			Density.	Tenacity.
No. of	How taken.	Numbers.		
3	Tangentially......	1, 2, and 3	7.3297	34348
3	Longitudinally ...	12, 13, and 14	7.3311	34212
3	Radially	20, 21, and 22	7.3224	34128

Maximum and minimum tenacities and densities.

Specimens.	Densities.		Tenacities.	
How taken.	Maximum.	Minimum.	Maximum.	Minimum.
Tangentially	7. 3725 O	7. 2867 M	38438 O	29099 M
Longitudinally	7. 8771 I	7. 2718 M	38236 I	80947 M
Radially	7. 3574 O	7. 2875 I	84630 O	33213 I

Abbreviations: O=specimen taken from exterior of ring; I=specimen taken from interior of ring, next the bore; M = specimen taken from middle of ring.

Initial tension.

Exterior diameter of ring	inches..	57. 15
Width of slot, before rupture	do....	. 5
Width of slot, after rupture	do....	. 6615
Total extension on exterior	do....	. 1615
Extension per linear inch on exterior	do....	. 000899511
Initial tension	pounds..	15, 750

WATERTOWN TESTS.

Tensile strength.

Specimens:

Number of		2.
Length of specimen between datum lines	inches..	28. 5
Diameter	do....	1. 129
Area of	square inches..	1
Hardness	inches..	15. 82
Specific gravity	do....	7. 2394

Ultimate strength at rupture:
Watertown No. 422 (S. B. I. Works, No. 4)=25, 000 pounds per square inch.
Watertown No. 423 (S. B. I. Works, No. 5)=26, 970 pounds per square inch.

These two tensile specimens were taken from the breech ring. They were taken out tangentially and next to the bore.

MUZZLE RING.

Initial tension.

Exterior diameter of ring	inches..	25. 76
Width of slot, before rupture	do....	. 49
Width of slot, after rupture	do....	. 50
Total extension on exterior	do....	. 01
Extension per linear	do....	. 000123
Initial tension inch on extension	pounds..	3, 500

The initial tension (3,500 pounds) above given is based upon the tests of the longitudinal specimens taken from the breech ring.

The tests of the specimens from the muzzle ring were all made at Watertown Arsenal and have not yet been received at this office.

CENTER OF GRAVITY.

The gun was designed to be without preponderance, hence the axis of the trunnions had to be so placed as to intersect the axis of piece at the center of gravity.

DETERMINATION.

(1) *By calculation.*—The calculated position of this center was determined by assuming the gun to be homogeneous cast-iron and to have the steel bushing and steel breech block in place. The weights of the bushing and block were calculated by assuming the average density for homogeneous gun steel. In this determination the console, lever, hanger, and spindle were neglected.

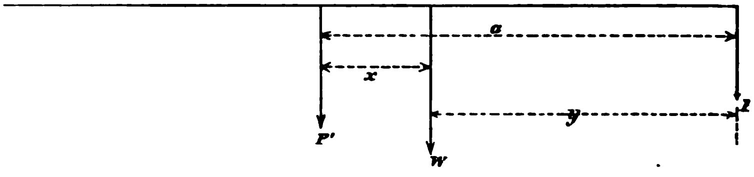
This method placed the center of gravity of the gun 239.8 inches from the muzzle.

(2) *By balancing wooden model one-tenth size.*—A model was made of hard pine, with the breech block of the same material. The wood used for this model was as uniform in texture as could be procured, and the model was one-tenth ($\frac{1}{10}$th) the size of the finished gun with the trunnions omitted. The mass of the trunnions being symmetrically disposed about the center of gravity would not affect its position.

This model was then balanced on a knife edge, keeping the bore horizontal, and the distance of the center of gravity from the muzzle measured. By this method the center of gravity of the gun was 240 inches from the muzzle.

(3) *By balancing the gun itself.*—It was deemed desirable to determine the center of gravity as accurately as could be done by experiment, in order to check the results of calculation and determine what variation would be found due to variations in density, in departure from the prescribed dimensions in manufacture, &c.

For this purpose the gun was finished upon the exterior and interior, the breech-block and bushing inserted, the console hung upon the rear end so that its center of gravity occupied the same position as when the mechanism should be assembled, and the trunnions were "rough turned," leaving the diameter as great as possible. The projection on the bushing intended to engage the lever on the final assembly of the parts was left necessarily, but its weight was offset by the omission of the lever and hanger. The trunnions were leveled on sections of railroad iron and the axis of the bore made horizontal. The breech was supported by a rope suspended from a hook attached to a scale-beam so as to weigh the preponderance directly. The rope was placed in contact with the face of the breech. The distance from the face of the breech to the center of the rough trunnions was measured. No platform scales of sufficient capacity to weigh the gun being available, its weight had to be assumed. The weight determined by calculation was 54 tons, of 2,000 pounds each, or 108,000 pounds. The diagram (not drawn to scale) and notation given below, exhibit the method pursued.



M=muzzle; B=breech; M B=axis of gun; D=center of rough trunnions; C=center of gravity of gun; P=preponderance referred to center of rough trunnions, determined by the steelyards; P′=component of the weight, acting at D, obtained by difference; W=weight of gun (calculated); a=measured distance from center of rough trunnions to face of breech; x=distance center of gravity in rear of center of rough trunnions; $a-x$=distance of center of gravity from face of breech.

Then

$W=108{,}000$ pounds. $P=864$ pounds. $a=120.2$ inches.

Hence:

$$P'=W-P=108{,}000-864=107{,}136 \text{ pounds.}$$

Now,

$$W:P::a:x=\frac{Pa}{W} \quad \ldots\ldots\ldots \quad (1)$$

Or 108,000 lbs.: 864 lbs. :: 120″.2: x=0″.9616=distance of center of gravity in rear of axis of rough trunnions.

And

$a-x$=120″.2—0″.9616=119″.2384=distance of center of gravity from breech.

And

$$W:P'::a:y=\frac{P'a}{W} \quad \ldots\ldots\ldots \quad (2)$$

or 108,000 : 107,136 :: 120″.2 : y=119″.2093=distance of center of gravity from face of breech.

Or $a-y$=120″.2—119.2093=x'=0″.9907=distance of center of gravity of gun in rear of axis of trunnions.

These values of x show a difference of 0″.0291, which is reasonably close considering the coarse means of measurement and weighing. The lesser value, 0″.96+ was assumed to be the distance that the axis of the trunnions should be moved to the rear. But the diameter of rough trunnions=16″.9; diameter of finished trunnions=15″; difference=1″.9; ½ difference=″.95=the greatest distance the trunnion axis could be moved towards the rear.

The axis of the trunnions was then ordered to be placed as far to the rear as the metal would allow, consistently with proper finishing. This distance was found to be only ″.95 instead of ″.96 as required by calculation. This places the axis of the trunnions at 119.25 from the breech.

RECAPITULATION.

Distance of center of gravity from muzzle of piece as determined.

	Inches.
1. By calculation, as per drawing	=239.8
2. By balancing wooden model $\frac{1}{10}$ size	=240.0
3. By balancing gun and subsequent computation	=240.76
4. Actual position of trunnions	=240.75

REMARKS.

The greater part of the measurements upon this gun were made by Lieut. H. D. Borup, Ordnance Department, U. S. A., Assistant Inspector of Ordnance at this foundry, who has also rendered valuable assistance in the preparation of this report.

TABLE VI.—*Record of measurements with star gauge of 12-inch cast-iron B. L. rifle.*

Distance from muzzle.	Diameter of bore.		Diameter of rifling.	Distance from muzzle.	Diameter of bore.		Diameter of rifling.	Distance from muzzle.	Diameter of bore.		Diameter of rifling.
	Horizontal.	Vertical.			Horizontal.	Vertical.			Horizontal.	Vertical.	
In.	*Inches.*	*Inches.*	*Inches.*	*In.*	*Inches.*	*Inches.*	*Inches.*	*In.*	*Inches.*	*Inches.*	*Inches.*
1	12.001	11.999	12.120	74	11.999	12.014	12.118	147	12.000	12.001	12.119
2	12.001	11.999	12.120	75	11.999	12.013	12.118	148	12.000	12.001	12.119
3	12.001	11.999	12.120	76	12.000	12.011	12.118	149	12.000	12.000	12.119
4	12.001	11.999	12.119	77	12.000	12.007	12.118	150	12.000	12.001	12.1195
5	12.002	11.999	12.119	78	12.000	12.011	12.1185	151	12.000	12.001	12.1195
6	12.001	11.999	12.120	79	12.000	12.009	12.118	152	12.000	12.001	12.118
7	12.001	11.999	12.120	80	12.000	12.009	12.118	153	11.999	12.001	12.118
8	12.002	11.999	12.119	81	12.000	12.009	12.118	154	11.999	12.000	12.118
9	12.002	11.999	12.119	82	12.000	12.009	12.118	155	12.000	12.001	12.118
10	12.001	11.999	12.119	83	12.000	12.009	12.118	156	12.000	12.001	12.118
11	12.001	11.999	12.119	84	12.000	12.009	12.118	157	12.000	12.001	12.118
12	12.000	11.998	12.120	85	12.000	12.008	12.117	158	11.999	11.999	12.119
13	11.999	11.998	12.120	86	12.001	12.008	12.118	159	11.999	11.999	12.119
14	11.999	11.998	12.120	87	12.001	12.007	12.118	160	11.999	11.999	12.120
15	11.999	11.998	12.120	88	12.001	12.006	12.118	161	12.000	11.999	12.121
16	11.999	11.998	12.120	89	11.998	12.013	12.119	162	12.000	11.999	12.119
17	11.999	11.998	12.119	90	11.999	12.013	12.118	163	12.000	11.998	12.120
18	11.999	11.998	12.119	91	11.999	11.999	12.118	164	12.000	11.998	12.120
19	12.000	11.998	12.119	92	11.998	11.998	12.118	165	12.000	11.999	12.119
20	11.998	11.998	12.119	93	11.999	11.998	12.118	166	11.999	11.998	12.118
21	12.000	11.998	12.119	94	11.999	11.998	12.118	167	12.001	11.998	12.118
22	12.000	11.999	12.119	95	12.000	12.000	12.118	168	12.001	11.999	12.118
23	12.000	11.999	12.119	96	12.000	12.000	12.118	169	12.001	12.001	12.118
24	12.000	11.999	12.120	97	11.999	12.000	12.118	170	12.001	12.001	12.118
25	11.999	11.999	12.121	98	11.999	11.999	12.119	171	12.000	12.000	12.119
26	11.998	11.999	12.120	99	11.998	11.999	12.119	172	12.000	12.001	12.119
27	11.998	11.999	12.120	100	11.998	11.999	12.1185	173	12.001	12.001	12.120
28	11.998	12.000	12.120	101	11.998	11.999	12.119	174	12.000	12.002	12.120
29	11.998	12.002	12.118	102	11.9985	11.999	12.119	175	11.9995	12.002	12.121
30	11.998	12.002	12.118	103	11.998	11.999	12.119	176	12.000	12.001	12.121
31	11.998	12.002	12.118	104	11.998	11.999	12.119	177	12.000	12.002	12.121
32	11.996	12.002	12.118	105	11.998	11.999	12.120	178	12.000	12.002	12.120
33	11.998	12.002	12.117	106	11.999	11.998	12.119	179	12.000	12.001	12.120
34	11.998	12.002	12.117	107	11.998	11.998	12.119	180	12.000	12.001	12.119
35	11.998	12.002	12.118	108	11.998	11.998	12.119	181	12.000	12.000	12.119
36	11.998	12.001	12.118	109	11.999	11.998	12.118	182	11.999	12.000	12.120
37	11.999	11.999	12.118	110	11.999	11.998	12.118	183	11.999	11.999	12.119
38	11.999	11.998	12.118	111	11.999	12.000	12.118	184	11.999	11.998	12.120
39	11.999	11.999	12.119	112	11.999	11.999	12.118	185	11.999	11.999	12.120
40	11.999	12.000	12.119	113	12.000	11.999	12.118	186	11.999	12.000	12.119
41	11.999	11.999	12.120	114	12.000	11.999	12.119	187	11.999	12.000	12.119
42	11.998	11.999	12.120	115	11.999	11.999	12.119	188	11.998	12.000	12.119
43	11.999	11.999	12.120	116	12.000	11.999	12.119	189	11.999	12.000	12.118
44	11.999	11.998	12.118	117	11.999	12.000	12.120	190	11.999	12.000	12.119
45	11.999	11.998	12.118	118	11.999	12.000	12.119	191	12.000	11.999	12.119
46	11.999	12.000	12.119	119	11.998	11.999	12.119	192	12.001	11.999	12.119
47	11, 998	12.000	12.119	120	11.998	12.000	12.120	193	12.001	11.999	12.119
48	11.999	12.000	12.119	121	12.000	12.000	12.120	194	12.000	11.999	12.119
49	11.998	11.999	12.120	122	11.999	12.000	12.119	195	12.000	11.999	12.121
50	11.999	11.998	12.120	123	11.999	11.999	12.118	196	12.000	11.999	12.120
51	11.999	11.998	12.119	124	11.999	12.000	12.117	197	12.000	11.999	12.119
52	11.999	11.999	12.120	125	12.000	12.000	12.1175	198	12.001	12.000	12.119
53	11.999	11.999	12.120	126	12.000	11.999	12.117	199	12.000	12.999	12.119
54	11.999	12.003	12.119	127	11.999	11.999	12.117	200	12.000	11.999	12.120
55	11.999	12.005	12.119	128	12.000	11.999	12.118	201	12.000	11.999	12.119
56	12.000	12.004	12.119	129	12.000	11.999	12.119	202	12.000	11.999	12.1185
57	11.998	12.004	12.120	130	12.000	11.999	12.119	203	12.000	11.999	12.119
58	12.000	12.005	12.120	131	12.000	11.999	12.120	204	11.9995	11.999	12.1185
59	11.999	12.004	12.120	132	12.000	11.999	12.120	205	11.998	11.999	12.119
60	12.000	12.003	12.119	133	11.999	12.000	12.120	206	11.999	11.999	12.119
61	11.999	12.000	12.119	134	12.000	12.000	12.119	207	11.998	12.000	12.119
62	11.999	12.0005	12.119	135	12.000	12.000	12.119	208	11.998	12.000	12.119
63	11.999	12.0005	12.119	136	12.000	12.000	12.118	209	11.998	12.000	12.119
64	11.999	12.0005	12.119	137	12.000	12.001	12.118	210	11.998	12.000	12.119
65	11.998	12.003	12.118	138	12.000	12.001	12.118	211	11.998	12.000	12.119
66	11.999	12.004	12.119	139	12.001	12.001	12.118	212	11.998	12.000	12.1185
67	12.001	12.008	12.120	140	12.000	12.000	12.1175	213	11.998	12.000	12.118
68	12.002	12.009	12.120	141	12.000	12.000	12.118	214	11.998	12.000	12.119
69	12.002	12.012	12.119	142	12.000	12.000	12.119	215	11.998	12.000	12.119
70	12.000	12.013	12.119	143	12.000	12.000	12.119	216	11.998	12.000	12.118
71	11.999	12.014	12.119	144	11.999	12.001	12.119	217	11.998	11.999	12.117
72	12.000	12.015	12.119	145	11.999	12.001	12.118	218	11.998	12.000	12.118
73	12.000	12.015	12.119	146	11.999	12.001	12.120	219	11.998	11.999	12.1175

TABLE VI.—*Record of measurements, &c.*—Continued.

Distance from muzzle.	Diameter of bore.		Diameter of rifling.	Distance from muzzle.	Diameter of bore.		Diameter of rifling.	Distance from muzzle.	Diameter of bore.		Diameter of rifling.
	Horizontal.	Vertical.			Horizontal.	Vertical.			Horizontal.	Vertical.	
In.	*Inches.*	*Inches.*	*Inches.*	*In.*	*Inches.*	*Inches.*	*Inches.*	*In.*	*Inches.*	*Inches.*	*Inches.*
220	11.998	11.999	12.118	260	12.000	11.999	12.121	305	13.497	....	....
221	11.998	11.999	12.1185	261	12.000	11.999	12.120	306	13.497	....	....
222	11.998	11.999	12.121	262	12.000	11.999	12.120	307	13.497	....	....
223	11.998	11.999	12.1205	263	12.000	11.999	12.120	308	13.497	....	....
224	11.998	11.999	12.1205	264	12.000	11.999	12.121	309	13.497	....	....
225	11.998	11.999	12.121	265	12.000	11.999	12.120	310	13.497	....	....
226	11.998	11.999	12.121	266	12.000	12.000	12.1205	311	13.496	....	....
227	11.998	11.9985	12.121	267	12.000	11.999	12.1205	312	13.497	....	....
228	11.998	11.998	12.121	268	12.000	11.999	12.121	313	13.496	....	....
229	11.997	11.999	12.1185	269	12.000	11.998	12.120	314	13.497	....	....
230	11.996	11.998	12.118	270	12.000	11.998	12.121	315	13.497	....	....
231	11.996	11.998	12.118	271	12.000	11.998	12.121	316	13.498	....	....
232	11.996	11.999	12.121	272	12.000	11.998	12.121	317	13.497	....	....
233	11.998	11.999	12.122	273	12.000	11.998	12.120	318	13.498	....	....
234	11.998	11.998	12.121	to	Front slope of chamber.			319	13.497	....	....
235	11.997	11.999	12.121	281				320	13.497	....	....
236	11.998	11.998	12.1215	282	13.499	....	....	321	13.497	....	....
237	11.996	11.999	12.122	283	13.499	....	....	322	13.498	....	....
238	11.997	11.998	12.121	284	13.498	....	....	323	13.498	....	....
239	11.998	11.999	12.121	285	13.499	....	....	324	13.498	....	....
240	11.998	11.999	12.121	286	13.497	....	....	325	13.498	....	....
241	11.998	11.999	12.121	287	13.498	....	....	326	13.497	....	....
242	11.998	11.999	12.121	288	13.498	....	....	327	13.498	....	....
243	11.998	11.999	12.120	289	13.497	....	....	328	13.498	....	....
244	11.998	12.000	12.120	290	13.496	....	....	329	13.498	....	....
245	12.000	12.000	12.120	291	13.495	....	....	330	13.497	....	....
246	11.999	11.999	12.1205	292	13.496	....	....	331	13.497	....	....
247	11.999	11.999	12.121	293	13.497	....	....	332	13.498	....	....
248	11.999	....	12.1205	294	13.495	....	....	333	13.498	....	....
249	11.999	....	12.1205	295	13.497	....	....	334	13.498	....	....
250	11.999	....	12.121	296	13.497	....	....	335	13.498	....	....
251	12.000	11.999	12.122	297	13.497	....	....	336	13.498	....	....
252	12.000	11.999	12.121	298	13.498	....	....	337	13.497	....	....
253	12.000	11.999	12.121	299	13.497	....	....	338	13.497	....	....
254	12.000	11.999	12.122	300	13.498	....	....	339	13.497	....	....
255	12.000	11.999	12.121	301	13.497	....	....	340	....	....	....
256	12.000	11.999	12.122	302	13.497	....	....	341	Rear slope of chamber.		
257	12.000	12.000	12.122	303	13.497	....	....	342			
258	11.999	11.999	12.121	304	13.497	....	....	343			
259	11.999	11.999	12.121								

TABLE I.—*Statement of fabrication of ordnance for the service of the United States by the South Boston Iron Works, at the South Boston Foundry, under the supervision of Capt. D. A. Lyle.*

[12-inch cast-iron B. L. R. gun. Cast May 6, 1884. Inspected April 1, 1885.]

CHARGE.

Iron used.

Grade of iron.	Furnaces.			
	No. 1.	No. 2.	No. 3.	Total.
	Tons.	*Tons.*	*Tons.*	*Tons.*
No. 1	0	0	0	0
No. 2	7	7	7	21
No. 3*, hard	9	9	9	27
No. 3, soft	8	8	8	24
Remelted	12	12	12	36
Total	36	36	36	108

* Classed as No. 4 Richmond at this foundry.

Coal consumed.—Not kept accurately; approximately, 55 tons.
Character of test sticks.—No record kept.

RECORD OF CASTING.

Furnaces fired, May 6, at 2 a. m.
Melted down at 11 a. m.
Time of melting, 9 hours.
Time in fusion, 5h. 25m.
Gun cast at 4.25 p. m.
Time occupied in casting, 23 minutes.
Temperature of water entering core-barrel, 52 degrees.
Temperature of water leaving core-barrel, 88 degrees.
Rate of water per minute, 40 gallons.
Fire kindled in pit, May 6, 5.30 p. m.
Fire in pit went out, May 7, 11.30 p. m.
Fire in pit burned 30 hours.
Water shut off, May 8, at 10 a. m.
Core-barrel removed at 11.30 a. m.
Water entered gun at 12 m.
Rate of water per minute, 40 gallons.
Temperature of water entering gun, 5 degrees.
Temperature of water leaving gun, 116 d grees.
Rate of water changed, May 12, at 9 a. m to 5 gallons.
Total time in cooling gun, 158¼ hours.

COOLING TABLES.

Core-barrel.				Core-barrel removed.													
Hours.	Degrees.	Hours.	Degrees.	Hours.	Degrees.	Hours.	Degrees.	Hours.	Degrees.	Hours.	Degrees.	Hours.	Degrees.	Hours.	Degrees.	Hours.	Degrees.
1	88	21	77½	*41	......	61	87	81	73	101	61	121	56	141	68½
2	88	22	77	*42	......	62	86	82	72	102	60	122	56	142	68½
3	88	23	77	43	116	63	86	83	72	103	60	123	56	143	68½
4	86	24	76½	44	112	64	85	84	71	104	60	124	56	144	68
5	84	25	76	45	110	65	84	85	70	105	59	125	56	145	68
6	83	26	75	46	108	66	83	86	69	106	59	126	56	146	67
7	81	27	75	47	107	67	82	87	68½	107	58	127	55	147	67
8	80	28	75	48	105	68	81	88	68	108	58	128	55	148	67
9	80	29	74	49	103	69	80	89	67½	109	58	129	55	149	67
10	80	30	74	50	101	70	79	90	66½	110	58	130	55	150	66½
11	79	31	73	51	99	71	78	91	66	111	58	131	55	151	66½
12	79	32	71	52	98	72	77½	92	65½	112	58	132	55	152	66
13	79	33	71	53	96½	73	77	93	65	113	58	133	55	153	66
14	79	34	71	54	95	74	76	94	64	114	58	134	55	154	66
15	79	35	70	55	94	75	76	95	63½	115	58	135	55	155	65½
16	79	36	70	56	93	76	75	96	63	116	58	136	70	156	65½
17	79	37	70	57	92	77	74	97	62	117	57	137	69	157	65½
18	79	38	69	58	91	78	74	98	62	118	57½	138	69	158	65
19	78½	39	69	59	89	79	73½	99	61½	119	57½	139	69	158¼	65
20	78	40	69	60	88	80	73	100	61	120	57	140	68½	......	......

* Hoisted core-arbor.

MECHANICAL TESTS.

(See p. 484 Report of Chief of Ordnance, U. S. A., for 1884, and bod of this report.)

TENSILE STRENGTH.

(See above remark.)

INITIAL TENSION.

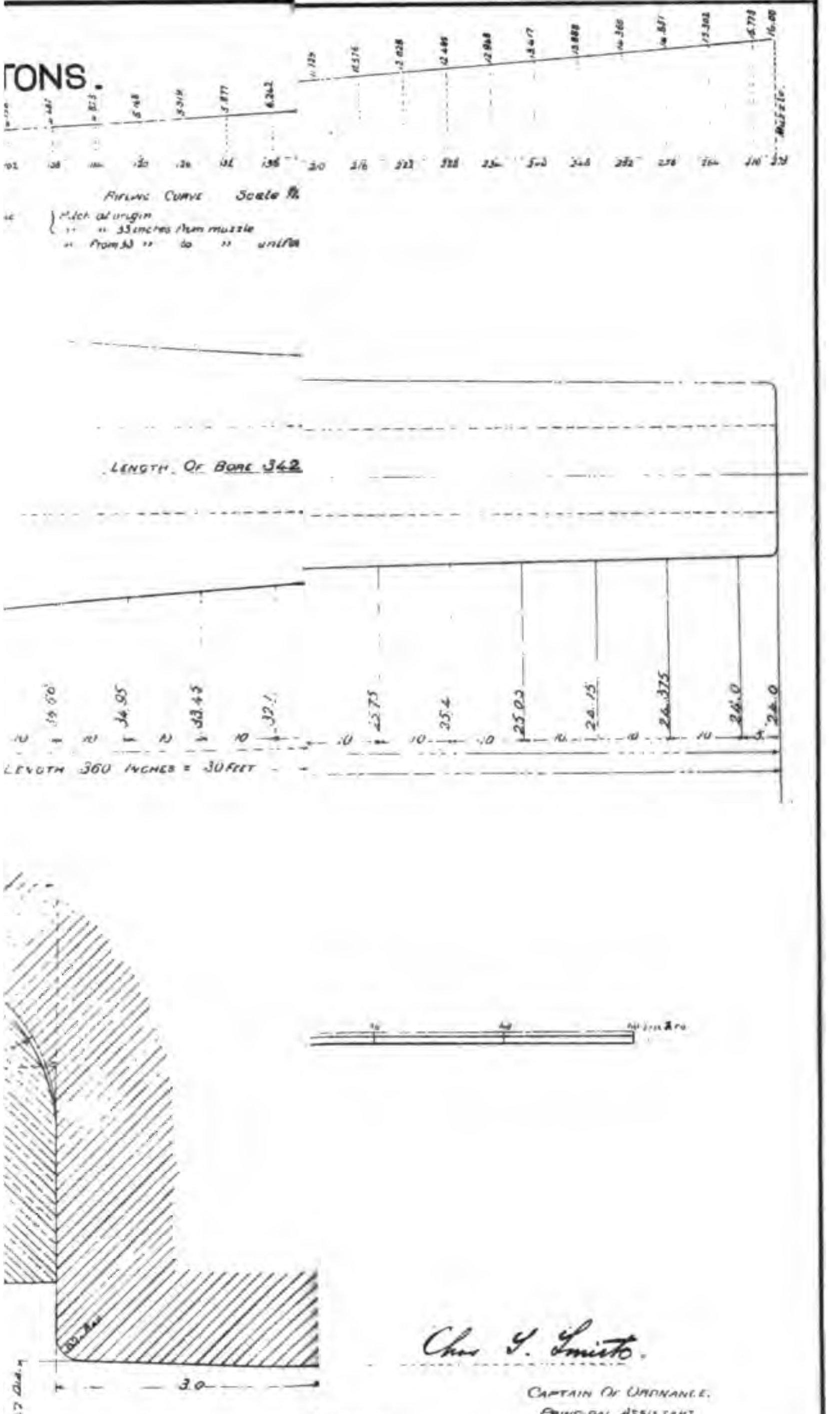
	Exterior diameter of ring.	Interior diameter of ring.	Thickness of ring.	Exterior opening.	Circumference of exterior of ring.	Extension per inch of circumference.	Initia tensio
	Inches.	*Inches.*	*Inches.*	*Inch.*	*Inches.*	*Inch.*	*Poun*
Breech	57.15	......	3	0.1615	179.544	.000899511	15,
Muzzle	25.78	10.58	3	0.01	80.9276	.000123	*3,

* From data given by long specimen taken from breech ring.

REMARKS.—The entire operation and superintendence of and responsibility for the casting w under the direction of the founders, and the only supervision exercised by the inspectors was that quired by the contract, so far as it provides for inspections at every stage of the manufacture.

PLATE I.

TONS.



Chas. S. Smith.

Captain Of Ordnance.
Principal Assistant.

24—1885.

APPENDIX 25.

CONSTRUCTION REPORT OF THE 12-INCH CAST-IRON RIFLED MORTAR, HOOPED WITH STEEL.

BY CAPT. D. A. LYLE AND LIEUT. H. D. BORUP, ORDNANCE DEPARTMENT.

(5 plates.)

TIME EMPLOYED.

The cast-iron body for this mortar was contracted for under date of September 24, 1883. The mortar was finished, fitted, assembled, rifled, and vented under a contract dated June 28, 1884, and was ready for shipment November 29, 1884. Thus, it was 1 year, 2 months, and 5 days from the date of the first contract until the finished product was ready for shipment.

The time required would have been less had it not been for the delay necessary to obtain a proper grade of iron and to make experimental mixtures for trial cylinders.

DESCRIPTION.

This mortar consists of a cast-iron body with the reinforce encircled and compressed by two rows of steel hoops.

THE CAST-IRON BODY.

The body is divided into the breech, reinforce, shoulder, chase, and bore.

The breech is sphero-segmental with a radius of 34.5 inches. Its surface is joined to that of the reinforce by a surface whose radius of curvature is 4.5 inches.

The reinforce is cylindrical and extends from the breech to the shoulder in front.

The shoulder is cylindrical and of larger diameter than the reinforce, to which it is connected in rear by a curved surface whose radius is 0.25 of an inch.

The chase is a frustum of a cone.

The bore is cylindrical with a cylindro-elliptical chamber.

THE STEEL HOOPS.

These are 14 in number, consisting of 13 cylindrical or common hoops made of Midvale steel, and one trunnion ring or hoop made of Whitworth steel. They are arranged in two rows or layers, as follows:

First, or inside row, eight hoops, viz: A_1 A_2 A_3 A_4 A_5 A_6 A_7 A_8.

Second, or outside row, six hoops, viz: B_1 B_2 (trunnion) B_3 B_4 B_5 B_6.

Rows A and B are both numbered from the front.

ALLOWED VARIATIONS.

From prescribed diameters:	
In turning	0.003
In boring	0.003
From parallelism of ends	0.003
For eccentricity	0.003
For conicalness	0.003
From absolute shrinkage:	
Between cast-iron body and inner row of hoops	+0''.003 —0 .000
Between the two rows of hoops	—0''.003 +0 .000
For finishing cut on bore	+0''.003 —0 .000
For finishing exterior of row B	+ 0''.02
Depths of rifling:	
Maximum	
Minimum	0.060

Joints or spaces between hoop, snot prescribed.

PRINCIPAL DIMENSIONS.

Total length of mortar	Inches	127.45
Length of rifled portion of bore	do	92
Length of chamber	do	19.25
Total length of bore	do	111.25
Diameter of bore	do	11.998
Diameter of chamber	do	11.848
Thickness of metal at breech	do	16.2
Body—		
Reinforce:		
Length under hoops of row A	do	65.75
Length under hoops of row B	do	54.75
Diameter before hooping (approximate)	do	*31.03
Shoulder—		
Length	do	4
Diameterm	do	32.53
Chase—		
Length	do	49.5
Diameter rear base	do	32.53
Diameter front base (muzzle)	do	22.54

STEEL HOOPS.

Row A (inside row):		
Number of		8
Total length of hoops	Inches	65.75
Diameter of hoops—		
Interior	do	†30.99
Exterior (except A_1)	do	†35.93
Thickness	do	†2.5
Hoop A_1:		
Diameter exterior	do	†37.1
Thickness	do	†3.05
Row B (outside row):		
Number of		6
Total length of hoops	Inches	54.75
Diameter of hoops—		
Interior	do	†35.89
Exterior (except B_3)	do	†41.59
Thickness	do	†2.8
Trunnion hoop (B_3):		
Length	do	†14.00
Diameter—		
Interior	do	†35.89
Exterior	do	†42.45
Thickness	do	†3.28

---

* The diameter of cast-iron body varies for the different zones under the hoops.
† Approximate.

Trunnions:		
Length	inches..	6
Diameter	do....	11.99
Distance from trunnions to muzzle	do....	74.92

RIFLING.

The rifling is polygroove, having an equal number of lands and grooves, and with the twist first increasing and then uniform to the muzzle.

DETAILS.

Grooves:		
Number		40
Width	inches..	0.6425
Depth	do....	0.0595
Width of lands	do....	.3
Radius of fillet, bottom of lands	do....	.08
Lands rounded with radius of	do....	.01
Twist:		
Increasing: at origin, one turn in 100 calibers; at 3.5 inches from muzzle, 1 turn in 35 calibers		
Uniform: at 3.5 inches from muzzle, 1 turn in 35 calibers; at muzzle, 1 turn in 35 calibers		
Total length of rifled portion of bore	inches..	92
Length of bore having increasing twist	do...	88.5
Length of bore having uniform twist	do...	3.5

VENTING.

The vent (0.2 inch in diameter) has a copper bushing, with a cylindrical body 1 inch in diameter, terminating at one end in a screw of 8 threads per inch, .98 inch in diameter for 2.875 inches of its length. At the other end is a head 0.75 inch long, whose lower cylindrical portion (1.5 inches in diameter) is flush with the highest part of the hoop, while the projecting portion is hexagonal, to facilitate its removal, when necessary, by means of a wrench. The lower end of the vent-bushing is shaped to the curve of the surface of the chamber.

POSITION OF VENT.

Distance from bottom of chamber	inches..	4.95
Distance to left of vertical plane through axis	do...	3

MARKS.

This mortar is marked upon the face with the following letters and characters placed in a circle concentric with the bore, viz: "12-In.—S. B. I. W.—1884.—D. A. L.—Wt. 30330 lbs."

FABRICATION.

CASTING FOR THE BODY.

The contract provides that "all these [four other castings are included in provision] castings shall be made hollow and be cooled from the interior (except as hereinafter provided for) by a current of air or water, the exterior at the same time being kept hot either by a fire built around the flask within the casting pit, or by filling the space between the flask and the pit-walls with some suitable non-conducting material, as may be desired by the United States. Specimens of the metal taken from the lower end of the sinking heads shall in each have an ultimate tenacity of not less than 30,000 pounds nor more than 37,000 pounds per square inch. The exterior dimensions of the rough castings shall be such as to allow the finishing of the guns to accurately conform to the dimensions given in the drawings hereto attached, and also to assure a uniform surface when finished; and the castings shall be sound, free from cavities, soft spots, and flaws."

In addition to these general specifications, the following pertain especially to the body for the 12-inch mortar:

"The casting for the body for the twelve (12) inch mortar shall be made breech down, and, inclusive of the sinking head, shall be nearly cylindrical—the exterior diameter at no place being less than at the breech—the total length exclusive of the sinking head being great enough to allow for a cylinder eighteen (18) inches long, to be taken from next the muzzle. The weight of the sinking head shall be at least one-sixth ($\frac{1}{6}$) of the total weight of the rough gun casting and cylinder. The part of the casting to which steel hoops are to be applied shall be turned to within four-tenths ($\frac{4}{10}$) of an inch of the finished diameter; the remainder of the exterior shall be finished turned."

TRIAL CYLINDER.

The contract specified that "the cast-iron used for these guns [four others were included in same contract] shall be of charcoal pig, and of the standard quality prescribed by the Ordnance Department for the manufacture of heavy guns, the kinds and proportions of pig metal to be about the same as shall be employed in a trial cylinder of the usual form and dimensions employed by the Ordnance Department for this purpose (see drawing attached), to be previously cast by the party of the first part (the S. B. I. W.) * * * * Specimens from each cylinder to show an elastic limit of about 11,000 pounds per square inch, and an ultimate tenacity of not less than 30,000 nor more than 37,000 pounds per square inch."

Several small cylinders were cast as a preliminary to casting the trial cylinder, in order to experiment on different mixtures of pig-iron, and procure such mixture as would fulfill the requirements of the contract.

Four standard trial cylinders were cast before the company were satisfied to submit one to the Department for testing.

The third cylinder cast was selected by the S. B. I. Works as the one most likely to possess the required qualities, and was turned over to the Government for testing. This cylinder was cut up and tested at Watertown Arsenal, except the tenacity specimens given in the appendix to this report.

DIMENSIONS OF TRIAL CYLINDER.

	Inches.
Length	60
Cross-section—ellipse:	
Transverse axis	24
Conjugate	16.5

The mortar was not cast until March 1, 1884, the intervening time (five months and seven days from date of contract) being taken up in experimenting on proper mixtures of iron, endeavoring to procure proper quality of pig-iron, and in cutting up and testing the specimens from the trial cylinders, and submitting the results to the Department for its action.

For furnace charges, cooling-table, and details of casting, see appendix.

THE EXPERIMENTAL CYLINDER.

An experimental cylinder and initial tension ring were cut from the muzzle end of the casting. The initial tension ring was cut for initial tension, and then had the necessary specimens taken from it for testing.

The object of experiments on this cylinder was to ascertain the behavior of the cas-tiron and steel hoops under the calculated shrinkages, and learn what modifications would be necessary in the application of the hoops to the cast-iron mortar body. A separate report of these experiments will be forwarded as soon as it is completed.

The mortar body was ready for the reception of the hoops on April 19, except the finishing cut upon the exterior zones under the hoops, which could not be taken until the hoops were finished and the shrinkages determined.

HOOPING.

CONTRACT SPECIFICATIONS.

In regard to the hooping, the contract of June 28, 1884, specified that "the hoops will be applied to the cast-iron body in a horizontal position, and for this operation the party of the first part must supply a suitable press to keep the joints between hoops accurately closed while the applied hoop is cooling, and a circular sprinkling arrangement to hasten the cooling slightly at the (front) end of the hoop. The heating of the hoops for shrinking will be so conducted as to insure a uniform and not excessive temperature—just sufficient to allow the hoops to be slipped into place. During hooping a current of cold water will be circulated through the bore.

INSTRUCTIONS OF THE CHIEF OF ORDNANCE, U. S. ARMY, REGARDING THE HOOPING.

"The diameter for the inner row of hoops to be 31 inches and for the outer row 35.9 inches. The work must conform to the prescribed dimensions to within the variations allowed by the contract. As regards the respective lengths of the hoops, slight variations from the prescribed lengths are allowable, provided that the sum of the lengths shall equal the length of the part to be hooped. The distinctive mark of each hoop, as A_1, A_2, B_1, &c., should be preserved, and when turning for the prescribed shrinkages the part to be hooped will be divided into zones, and each zone be turned with special reference to the hoop corresponding to it, observing the order of the hoops shown in the drawing.*"

MEASUREMENTS OF HOOPS.

After "facing" the ends of each hoop to bring it to the required length, with the planes of the faces parallel, and turning the interior surface, the hoops were ready for the first measurement. The first step was to mark and number four diameters 45° apart upon one end, which was designated throughout the work as "the face."

The lengths of the hoop were measured both on the interior and exterior at the points where these diameters intersected the interior and exterior circumferences of the hoop.

The interior diameters were measured in the planes of the rectilinear elements, cut out by the series of planes passing through the axis and the four diameters marked consecutively, as above stated.

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* Official copy of blue print of 12-inch M. L. R. mortar, dated March 15, 1884.

The four rectilinear elements corresponding to the marked ends of the four diameters were outlined on the interior surface of the hoop by means of a try-square and scratch-awl, and then chalked. On each of these chalked elements a series of points were marked with pencil, as follows: At 0.1 inch from each end, and at intervals of 1 inch from the 0.1 inch point next to the marked face. The last interval, or longitudinal space, was generally greater than one (1) inch, as the 1-inch space would bring it quite close to the point 0.1 inch from the bottom.

The zones on the exterior of the mortar body, and on the exterior of row A, were finished, turned after their corresponding hoops had been bored or turned on the interior and measured.

The measured interior diameters of the hoops and the calculated shrinkages form the data for turning the exterior surfaces or zones.

Four diameters and four rectilineal elements were similarly outlined and marked upon the exterior of the body, and first row of hooping (Row A), to indicate the planes of measurement.

The lengths of the hoops were measured with vernier beam-calipers. The lengths of the zones on the mortar body and exterior of Row A were measured with a Brown & Sharpe scale.

The interior diameters of the hoops were measured with adjustable "points."

These points are steel wires surrounded by a wooden body, to prevent the heat of the hand from expanding the metal. One end is movable, and can be screwed in or out with a pin-wrench. The lengths of these "points" were determined after each measurement by means of the vernier beam-calipers adopted as the arbitrary standard to which all measurements were referred.

The exterior diameters of all zones or hoops were measured by the diameter calipers furnished from Frankford Arsenal which are sensitive to .001 inch, and may be readily estimated to .0005 inch.

(See diagram opposite.)

LIST OF MEASUREMENTS REQUIRED BY THE OPERATIONS OF HOOPING.

CAST-IRON BODY 12-INCH M. L. R. MORTAR.

Bore.—Horizontal and vertical diameters should be measured at the front end, middle, and rear end of each hoop. [These measurements should extend from the bottom of the bore to a point in front of the hoops where no further compression of the bore will take place (in this case about 5 inches).]

These measurements should be made with the star gauge as follows:

(1) After boring to 11.95.
(2) After application of Row A.
(3) After turning exterior of Row A (not done in this instance).
(4) After application of Row B.
(5) After turning exterior of Row B.
(6) After finish boring to 12 inches.
(7) After rifling: (a) Across lands; (b) across grooves.

Exterior.—Zones corresponding to each hoop (measured with Frankford diameter calipers).

(8) Four diameters 45° apart in each right section; (a) for section 0.1 inch from each end of zone; (b) for sections 1 inch apart throughout zone, beginning at a point corresponding to 0.1 inch from marked face of hoop.

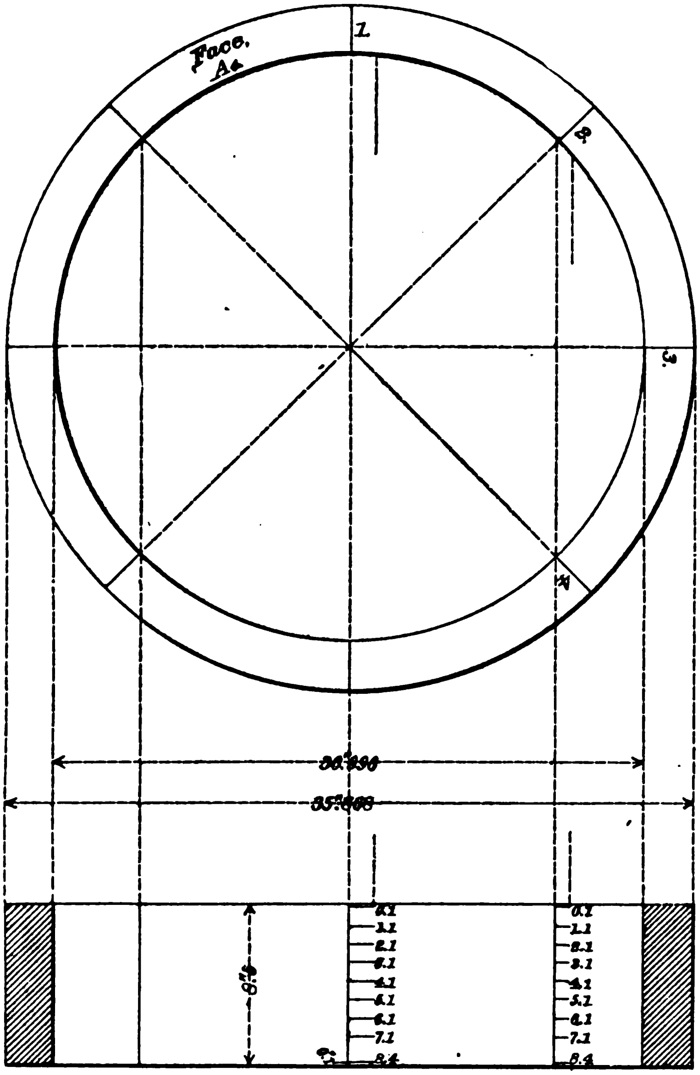
HOOPS.

Each hoop before application.

(9) Length (width) on exterior at ends of 4 diameters, 45° apart, with vernier calipers.

(10) Length (width) on interior at ends of 4 diameters, 45° apart, with vernier calipers.

PLAN.



SECTION AND ELEVATION.

Face p. 180

(11) Parallelism of faces at ends of 4 diameters, 45° apart (straight edge, try-square, and above measurements are used to determine parallelism).

(12) Interior diameters, four, 45° apart for each transverse section (adjustable rods and vernier calipers).

(a) At 0.1 inch from each face (adjustable rods and vernier calipers).

(b) At 1 inch apart throughout whole length of hoop (adjustable rods and vernier calipers).

After application Row A.

(13) Spaces between hoops equal opening of joints at top and bottom (standard brass slips used).

(14) Length of row of hooping, top, bottom, and sides (steel scale).

Exterior diameter-zones of Row A corresponding to each hoop of Row B.

(15) After turning exterior Row A to proper zones for Row B.

(a) At 0.1 inch from each end of zone (vernier calipers).

(b) At 1 inch apart throughout zone (vernier calipers).

Row B (16, 17, 18,) same as 13, 14, 15, for Row A.

NUMBER OF MEASUREMENTS.

Hoops: Row A.

Hoop.	Length.	Interior diameters.	Mortar zones under—	Length.	Exterior diameters.
A_1	16	28	A_1	4	28
A_2	16	36	A_2	4	36
A_3	16	36	A_3	4	36
A_4	16	36	A_4	4	36
A_5	16	32	A_5	4	32
A_6	16	36	A_6	4	36
A_7	16	36	A_7	4	36
A_8	16	36	A_8	4	36

Hoops: Row B.

			Corresponding zones of row A, under—		
B_1	16	32	B_1	4	32
B_2 (trunnion)	16	60	B_2	4	60
B_3	16	36	B_3	4	36
B_4	16	36	B_4	4	36
B_5	16	36	B_5	4	36
B_6	16	36	B_6	4	36
Sums	224	512	....	56	512
Total	....	....	....	....	1,304

	Number of measurements.
From above table	1,304
Length of hooped surface:	
Row A, at 4 points, 90° apart	4
Row B, on top and bottom	2
Spaces between hoops:	
Row A, at 4 points, 90° apart	32
Row B, at 4 points, 90° apart	24
Extra Star-gauge measurements of diameters rendered necessary by hooping	192
Grand total	1,558

N. B.—These measurements are exclusive of those usually taken on guns of same form. The latter measurements are inserted in the inspection report, as usual.

Number of men required for shrinking hoops on 12-inch M. L. R. mortar.

Foreman in charge of men	1
Taking temperatures of water in bore and reading gas-meter	1
To adjust hoop, tend heater, and adjust pressure collar	2
To tend gas and blast cocks and manage hoisting apparatus	1
To tend the hydraulic jack and apply the pressure	1
To handle the water ring—one on top of the mortar and one on each side	3
To note the time and superintend the various operations of the hooping	1
To record all data, make notes, and verify the lengths of the maximum and minimum wires used for measuring the expansion of the hoops	1
Total number of men required	11

[NOTE.—The functions of the last two men were performed by the inspectors.]

APPARATUS FOR HOOPING.

[Plates II–V.]

The general arrangement of the apparatus for hooping is shown in Plates I and II. Plate I gives a side elevation, and Plate II a plan and partial horizontal section, of the mortar and apparatus at the instant when the last hoop of row B was in position on the piece, and just before the adjustment of the water-ring for cooling the hoop.

The mortar was placed upon a wooden cradle with the muzzle resting in a transom, to which it was attached by an iron strap. A bolster was placed under it near the cylindrical shoulder at the rear end of the chase, and the rear end of the mortar was supported by a screw-jack placed under the turning tenon. This jack was removed by dragging to one side while the hoop and pressure-collar were being passed over the piece; but was replaced immediately thereafter.

The device for cooling the bore is made of iron in two parts, concentric, and so constructed as to slide within each other on an incline and produce a wedging action sufficiently great to develop friction enough to retain the muzzle-plug and support the pressure of the water in the bore. The water enters through a pipe into the chamber of the muzzle-plug, whence it flows through the bore, and makes its exit by means of a pipe extending through the muzzle-plug to within a few inches of the bottom of the bore. The quantity of water is regulated by suitable stop-cocks.

The hydraulic jack (power equal to 95 to 100 tons) is bolted at the base to the muzzle-plug. Its piston presses against a cross-head, to which the longitudinal tension bars for transmitting the pressure to the collar or ring in rear of the hoop is keyed with steel wedges. The tension-bars have a series of holes for the insertion of the steel keys in adjusting the lengths of the bars to correspond to the positions of the several hoops.

The rear ends of the tension-bars are T-shaped, so as to engage the slotted ears or pressure-lugs on the sides of the collar.

The pressure-collar is suspended by a ring-bolt, to which is fastened a pulley and fall attached to a movable carriage on the elevated rail overhead.

The hoop is similarly suspended in the heater, except that the ring-bolt is replaced by a split ring of wrought iron for sustaining the hoop. This split sustaining-ring is assembled at the top by a bolt and key passing through two eyes. As soon as the hoop is in position on the piece this key and bolt are knocked out, the ring opened and moved forward to be out of the way of the water-ring during the cooling of the hoop.

As soon as the gas is extinguished and the hoop is swung clear of the heater the latter is shifted to one side on the lateral railway, shown in plan in Plate III, to enable the pressure-collar to be brought up from the rear.

The hoisting apparatus is placed in rear on a line with the axis of the piece. The stop-cocks which regulate the gas and air blast are placed near this apparatus, so that one man can attend to all three.

A 2 inch rubber pipe makes a flexible connection between the air and gas pipes and the gas-furnace.

The gas heater or furnace, Plates II, III, IV, is made of gas-pipe let into a metallic nave. It resembles a wheel, and has 28 radial arms or spokes of gas-pipe—14 for the outside and 14 for the inside burners—arranged so that the burners alternate or break joints, as it were, on the exterior and interior of the hoop.

Each arm carries 3 burners, making a total of 84 burners. The aperture of each burner is elliptical, $0''.1875$ by $0''.8125$, ($\frac{3}{16} \times \frac{13}{16}$.) A few burners with circular apertures were tried, but did not prove so satisfactory as the flaring burners.

Each radial arm is made in two parts, sliding one within the other, for adjusting the burners to the proper distances from the hoop.

The wider the hoop the more burners are required on each arm.

The water-ring or sprinkling apparatus for cooling the hoops is made in two curved segments hinged at their upper ends, so as to open and close with facility. The segments are arcs of a circle with 60 inches radius. The front face of each segment is fitted with 19 movable gas brackets and burners placed 4.25 inches apart, each with a stop-cock. The usual silicate tip of the fish-tail burner forms to nozzle for each jet and produces a thin sheet of water. When in action the slits of these tips are all adjusted to coincide with a plane parallel to the plane of the gas-pipe segments, and their juxtaposition produces a thin sheet of water completely encircling the hoop, except a small space at the bottom. This arrangement enables the operator to cool any particular section of the hoop that he may desire. Even with a full head of water not more than 2½ inches in length of the hoop is cooled by this sheet, which spreads laterally upon impact.

The only trouble is in the loss of the tips, which are occasionally thrown out by the force of the water, or broken by striking the gun or hoops in oscillating to and fro when the whole surface of the hoop is being cooled. Extra tips are kept at hand, and it is but the work of an instant to replace one broken or lost.

The water may be let on in both segments or in only one, and may be shut off from any particular jet.

The drawings do not show this device in use. It is hoisted into place by the pulley and fall which carries the suspended hoop while heating, and replaces the split ring which encircles the hoop, as shown in Plate II, as soon as the hoop is in place.

This apparatus was very successful in its operation.

LENGTH OF EXPANSION-RODS EMPLOYED FOR TESTING THE EXPANSION OF THE HOOPS WHILE HEATING.

Row A.

Hoops.	Length of rod.	
	Maximum.	Minimum.
A_1........	31.1306	31.0996
A_2........	31.1306	31.0996
A_3........	31.1306	31.0996
A_4........	31.1046	31.0736
A_5........	31.1046	31.0736
A_6........	31.1035	31.0725
A_7........	31.1041	31 0731
A_8........	31.1055	31.0745

The lengths of the rods for A_1, A_2, and A_3 are governed by the exterior diameter of the fillet on the mortar corresponding to the depth of the groove accidentally cut in A_3. Their proper lengths, depending on their own diameters, would have been the following:

Hoops.	Length of rod.	
	Maximum.	Minimum.
For A_1	31.1041	31.0731
A_2	31.1043	31.0734
A_3	31.1055	31.0745

LENGTH OF EXPANSION-RODS EMPLOYED FOR TESTING THE EXPANSION OF THE HOOPS WHILE HEATING.

Row B.

Hoops.	Length of rod.	
	Maximum.	Minimum.
B_1	36.0217	35.9858
B_2 (trunnion)	36.0210	35.9851
B_3	36.0211	35.9852
B_4	36.0210	35.9851
B_5	36.0223	35.9864
B_6	36.0211	35.9852

METHOD OF HOOPING.

At this stage of the fabrication the cast-iron body for the mortar is supposed to be bored up to within 0''.05 of the finished diameter, and the zones into which the exterior surface is conceived to be divided are turned to their prescribed diameters, including the shrinkages.

The necessary measurements on the exterior and in the bore have also been made.

FIRST ROW OF HOOPS—(ROW A.)

Preparatory work.

(1.) Facing ends of hoops to make them parallel.

(2.) Turning interior of hoops.

(3.) Measuring interior diameters and length of hoops.

(4.) Placing mortar on cradle in a horizontal position for hooping.

(5.) Attaching water apparatus for cooling bore.

(6.) Placing hydraulic jack, tension-bars, &c., in position to hold hoops firmly in place while cooling.

(7.) Suspending pressure collar or ring ready for use.

(8.) Attaching water apparatus for cooling hoops to rolling pulley-block ready for hoisting.

(9.) Placing and adjusting small railway for gas-heater in rear of mortar.

(10.) Mounting gas-heater upon railway.

(11.) Attaching gas and air blast pipes to heater.

(12.) Suspending and adjusting hoop in sustaining-ring, and attaching latter to a rolling pulley-block running on an elevated rail dependent from the ceiling.

(13). Verifying the lengths of the maximum and minimum expansion-rods by means of the standard vernier-beam calipers.

(14). Taking initial reading of gas-meter.

(15). Turning on water in bore.

(16). Measuring number of gallons per minute that flows through bore.

(17.) Taking temperature of water flowing from hydrant.

OPERATIONS.

The mechanical operations of shrinking on hoops may be divided into three stages: 1, Heating; 2, Putting on; 3, Cooling.

HEATING.

This consists in suspending the hoop in the gas-heater so that the two circles of gas-burners (one around the interior and the other around the exterior surface of the hoop) are placed at a distance from the surface of the hoop, varying from 0″.75 to 1″.5, depending on the pressure of the gas, the pressure of the blast, and the strength of the currents of air developed by the heating or resulting from the wind pouring through cracks, doors, &c., in the foundry. These distances must be adjusted to suit the conditions present in each individual case, in order to get the maximum heating effect per cubic foot of gas and to secure uniformity in heating. After adjusting the hoop in the heater, the gas is turned on and lighted. The blast is turned on immediately and adjusted without delay. After heating a proper length of time, determined approximately by the previous trials with the experimental cylinder, the degree of expansion is tested with the minimum rod. To do this, the hoop is swung forward clear of the gas-jets and one end of the rod placed just within the edge at the bottom (as it hangs) of the hoop, and then the upper end is passed back and forth parallel to the face of the hoop to find the highest point at which it should enter if the hoop be sufficiently expanded.

This measurement should be made as quickly as possible to avoid unnecessary loss of heat by radiation and the hoop allowed to swing back in the flames until sufficiently expanded. The hoops were heated until the minimum rod entered, and then for a further interval determined by the judgment of the inspector in charge. This interval was in no case sufficient to cause an expansion of the hoop great enough to admit the maximum expansion-rod for that hoop.

PUTTING ON.

When the hoop was expanded until its interior diameter fell within the prescribed limits, the gas was extinguished and without delay the hoop was carried forward to the breech of the mortar by the rolling of the suspended pulley-block, engaged and slipped forward on the mortar body. The suspended pressure collar or ring was similarly brought up and placed upon the mortar and the two were pushed to the front until the hoop brought up in its position against the shoulder of the mortar body or the preceding hoop. As soon as the hoop was in position the tension bars were locked in the pressure collar and the pump of the hydraulic jack rapidly operated until the collar was brought to a moderate bearing against the hoop. Just about the instant of clamping, which had to be estimated, the full pressure of the jack was exerted and so continued to be exerted until the hoop was cold.

To prevent loss of time in adjusting the tension bars, blocks whose lengths are equal to the widths of the hoop with a slight excess, are cut and used to adjust the lengths of the tension bars to correspond with the distance from the head to the rear face of the pressure collar when the hoop is interposed. The keys are then set in the front end and the bars spread apart slightly and the blocks removed. With this arrangement all that is needed after the hoop and pressure collar are pushed forward to their proper positions, is to rotate these bars horizontally toward the mortar until they are fully engaged in the slotted lugs on the sides of the pressure collar. The pump on the jack may be operated immediately.

COOLING.

The water was turned on in the mortar to keep the bore cool, about the time the hoop was adjusted in the heater. After the hoop was in position and a moderate pressure applied, the water ring was hoisted and lowered into place, encircling the hoop. The estimated interval for the hoop to cool sufficiently to clamp the piece lightly was allowed to elapse and then the water was turned on around the front edge of the hoop to hasten the grip at that point. Meanwhile the full power of the press was exerted to keep the joints between the hoops as small as possible. The water plane, for such it virtually was from the method of construction of the ring, was at proper intervals moved successively to a point 1 inch in rear of the front face, to the middle of the hoop and to the rear end, pausing about one minute in each position.

The ring was then swayed back and forth so as to deliver the water from the middle of the preceding hoop to the rear of the hoop being shrunk on. This process prevented an objectionable rise of temperature in the hoop previously applied and at the same time cooled the hoop operated upon rapidly enough. This swaying of the water ring was continued until the exterior of the hoops and gun were cold. The temperature of the water coming from the bore was taken at intervals of one minute throughout the operation. It was found that the pressure collar became heated sufficiently from contact with the rear face of the hoop to interfere materially with the cooling of the hoop. To obviate this as much as possible a Johnson hand force-pump was used to throw a stream of water around the rear end of the collar and to keep the mortar body under it cool. The oscillations of the water ring were increased sufficiently to allow the water to strike upon the front end of the collar and thus materially assist in keeping down its temperature. After the first hoop was on and as soon as the second hoop was in position, the water was turned on at the middle of the preceding hoop to keep it as cool as possible, without, however, allowing the water to strike the heated hoop until it begun to clamp the mortar This course was also followed with good results for the remaining hoops.

HOOPS OF ROW B.

The operations attending the shrinking on of this row of hoops were identical with those employed for Row A.

Notes on application of Row A hoops to 12-inch M. L. rifled mortar.

[Date, October 9, 1884.]

Subjects of observation.	Hoops.							
	A_1	A_2	A_3	A_4	A_5	A_6	A_7	A_8
	A. M.	A. M.	P. M.	P. M.	P. M.	P. M.	P. M.	P. M.
	h. m. s.	*h. m. s.*	*h. m. s.*	*h. m. s.*	*h. m. s.*	*h. m. s.*	*h. m. s.*	*h. m. s.*
Hoop adjusted in heater	9 25 0	11 18 0	(*)	3 36 0	4 42 0	7 12 0	8 15 0	9 18 0
Gas lighted	9 28 0	11 21 0	2 12 30	3 37 0	4 43 0	7 15 0	8 18 0	9 19 0
Turned on blast	(*)	11 21 45	2 12 30	3 37 10	4 43 10	7 15 10	8 18 10	9 19 10
Blast adjusted	9 49 0	11 22 30	2 12 43	3 37 20	4 43 20	7 15 20	8 18 20	9 19 20
Minimum wire entered at	10 6 0	11 44 30	2 35 0	3 53 45	4 59 0	7 37 0	8 39 0	9 38 0
Maximum wire entered at	(†)	(†)	(†)	(†)	(†)	(†)	(†)	(†)
Gas turned off	10 8 0	11 48 30	2 36 0	3 55 20	5 0 15	7 37 0	8 40 0	9 39 0
Time of heating, estimated from time of lighting gas to extinguishing it	0 40 0	0 27 30	0 23 30	0 18 20	0 17 15	0 22 0	0 22 0	0 20 0
Time of heating after minimum wire entered	0 2 0	0 4 0	0 1 0	0 1 35	0 1 15	0 0 0	0 1 0	0 1 0
Gas consumed (cubic feet)	220	275	211	200	200	191	191	191
Color of hoop	(‡)	(‡)	(‡)	(§)	(§)	(§)	(§)	(§)
Began sliding hoop on	10 8 0	11 48 30	2 36 30	3 55 25	5 0 20	7 37 5	8 40 5	9 39 5
Hoop in position at	10 9 0	11 49 30	2 37 20	3 56 20	5 1 20	7 38 0	8 41 0	9 39 25
Time required to get hoop on	0 1 0	0 1 0	0 5 0	0 55 0	0 1 0	0 0 55	0 0 55	0 0 20
Pressure applied at	10 9 45	11 50 20	2 37 30	3 57 0	5 2 0	7 38 30	8 41 30	9 40 30
Time required to get press in action	0 0 45	0 1 0	0 0 10	0 0 40	0 0 40	0 0 30	0 0 30	0 1 5
Began adjusting water ring	(*)	11 50 15	2 38 0	3 57 0	5 2 0	7 39 30	8 42 30	9 43 20
Water ring in position	(*)	11 51 15	2 39 30	3 58 0	5 3 10	7 40 30	8 43 30	9 44 30
Time required	(*)	0 1 0	0 1 30	0 1 0	0 1 10	0 1 0	0 1 0	0 1 10
Water turned on (front end)‖	10 15 0	11 56 0	2 45 20	4 3 0	5 7 0	7 44 30	8 48 0	9 47 30
Water ring advanced 1″	10 18 0	11 59 0	2 47 0	4 5 0	5 8 0	7 45 0	8 50 0	9 49 30
Water ring advanced to center of hoop	10 20 0	12 1 0	2 48 0	4 7 0	5 10 0	7 46 0	8 55 0	9 50 30
Water ring over entire hoop at	10 21 0	12 2 30	2 50 0	4 8 0	5 11 0	7 46 30	8 56 0	9 51 30
Hoop cool at	10 52 0	12 25 0	3 14 0	4 26 0	5 25 0	8 0 0	9 1 0	10 14 0
Water turned off at	10 52 0	12 25 0	3 14 0	4 26 0	5 25 0	8 0 0	9 1 0	10 14 0
Time from getting hoop in place to turning on water (estimated time required for clamping)	0 6 0	0 6 30	0 8 0	0 6 40	0 5 40	0 6 30	0 7 0	0 8 5
Time water running	0 37 0	0 29 0	0 28 40	0 23 0	0 18 0	0 15 30	0 13 0	0 26 30
Time in cooling	0 44 0	0 36 30	0 38 0	0 30 40	0 24 45	0 23 0	0 21 0	0 35 0
Pressure removed	10 52 0	12 25 0	3 14 0	4 26 0	5 35 0	8 0 0	9 1 0	10 14 0

* Not taken.
† The maximum wire did not enter in any case.
‡ See remarks.
§ Brown.
‖ Time for clamping estimated.

Notes on application of Row B hoops to 12-inch M. L. rifled mortar.

[Date October 28, 1884.]

Subjects of observation	Hoops.						Remarks.
	B_1.	B_2.	B_3.	B_4.	B_5.	B_6.	
	A. M.	A. M.	P. M.	P. M.	P. M.	P. M.	
	h. m. s.	*h. m. s.*	*h. m. s.*	*h. m. s.*	*h. m. s.*	*h. m. s.*	
Hoop adjusted in heater							
Gas lighted	8 55 0	10 40 0	1 35 0	2 54 0	4 06 0	5 04 0	
Turned on blast	8 55 10	10 40 05	1 35 05	2 54 05	4 06 05	5 04 05	
Blast adjusted	8 55 35	10 40 30	1 35 10	2 54 20	4 06 10	5 04 10	
Minimum wire entered at	9 11 0	11 12 00 } V 11 22 20 } H	1 52 0	3 12 0	4 24 0	5 37 0	
*Maximum wire entered at							
Gas turned off	9 13 0	11 26 20	1 54 15	3 13 0	4 26 0	5 38 0	
Time in heating	0 18 0	0 46 20	0 19 15	0 19 0	0 20 0	0 34 0	
Time of heating after minimum wire entered	0 02 0	V } 14 20 H } 04 0	0 02 15	0 01 0	0 02 0	0 01 0	
Color of hoop	(†)	(‡)	(†)	(†)	(‡)	(‡)	
Began sliding hoop on	9 13 0	11 26 20	1 54 15	3 13 0	4 26 0	5 38 0	
Hoop in position at	9 14 10	11 27 45	1 55 15	3 14 20	4 26 30	5 38 10	
Time required to get hoop on	0 01 10	0 01 25	0 01 0	0 01 20	0 0 30	0 0 30	
Pressure applied at	9 14 15	11 30 0	1 56 15	3 14 30	4 26 40	5 38 30	
Time required to get press in action	0 0 5	0 2 15	0 0 60	0 0 10	0 0 10	0 0 20	
Began adjusting water ring	9 15 30	11 31 0	1 56 20	3 14 40	4 27 0	5 39 15	
Water ring in position	9 16 20	11 32 15	1 57 20	3 16 20	4 28 50	5 40 20	
Time required	0 0 50	0 01 15	0 01 0	0 01 40	0 01 50	0 01 05	
Water turned on (front end)	9 22 0	11 40 0	2 03 0	3 22 30	4 33 0	5 46 0	
Water ring advanced 1 inch	9 23 0	11 41 0	2 04 0	3 23 0	4 34 0	5 47 0	
Water ring advanced to center of hoop	9 24 0	11 43 30	2 06 0	3 23 30	4 35 0	4 48 30	
Water ring over entire hoop at	9 24 30	11 45 0	2 07 0	3 25 0	4 36 0	4 51 0	
Hoop cool at	9 42 30	12 19 0	2 23 0	3 40 0	4 52 0	6 10 0	
Time from getting hoop in place to turning on water (estimated time required for clamping)	0 07 50	0 12 15	0 07 45	0 08 10	0 06 30	0 07 50	
Time water running	0 20 30	0 39 0	0 20 0	0 19 30	0 19 0	0 24 0	
Time in cooling	0 29 30	0 52 40	0 28 45	0 27 0	0 26 0	0 22 0	
Pressure removed at	9 45 30	12 24 0	2 24 0	3 40 15	4 52 30	6 10 0	
Gas consumed (cubic feet)	285	610	225	250	240	260	

*The maximum wire did not enter in any case.

†Brown.

‡See remarks.

Temperature of water in bore during hooping.

[Flow of water through bore = 35 gallons per minute.]

Hoop.	Temperature of water in bore.					Time after hoops in position.			Duration of—		
						Before.					
	Hydrant.	At instant put on.	Maximum temperature.	Extreme range of.	When hoop cold.	Change of temperature.	Temperature normal again.	Observations taken.	Rise of temperature.	Maximum temperature.	Decrease of temperature.
	°	°	°	°	°	′	′	′	′	′	′
A_1	65.75	65.75	66.75	1.	65.75	15	44	46	6	22	3
A_2	65.75	65.75	66.	0.25	65.75	15½	35½	39½	1	19	1
A_3	65.75	65.75	66.	0.25	65.75	14	37	39	1	23	1
A_4	65.75	65.75	66.	0.25	65.75	16	30	32	1	14	1
A_5	65.75	65.75	66.	0.25	65.75	17	24	26	1	7	1
A_6	65.50	65.5	66.	0.5	65.5	16	22	24	3	2	3
A_7	65.50	65.5	66.	0.5	65.5	11	20	22	3	4	4
A_8	65.50	65.5	65.75	0.25	65.5	9	39	39	1	27	1
B_1	56.	56.	56.	0.0	56.	*	......	......	......	......	......
B_2 (trunnion)	56.	56.	57.	1.0	56.	27	53	53	6	16	6
B_3	56.	56.	57.	1.0	56.	17	28	28	7	3	3
B_4	56.5	56.5	57.5	1.0	56.5	16	28	31	5	4	4
B_5	56.	56.	56.	0.0	56.	*	......	......	......	......	......
B_6	56.	56.	56.	0.0	56.	*	......	......	......	......	......

* No change in temperature.

NOTE.—Thermometer readings were taken by an assistant at intervals of one minute from the instant the hoop was in position until it was cold.

Summary of the intervals of time required for the various operations of hooping the 12-inch M. L. rifled mortar.

Designation of hoop.	Time from igniting gas until—					Time of heating hoop.		Time required to get—			Time after hoop in position before water—							Length of time.			Color of hoop when gas turned off.	Gas consumed in expanding hoop.
	Blast.		Wire entered hoop.																			
	Blast turned on.	Blast adjusted.	Minimum wire entered at—	Maximum wire entered at—	Gas extinguished.	After minimum wire entered.	Total.	Hoop in position on mortar.	Pressure applied after hoop on.	Water ring in position after pressure applied.	Turned on preceding hoop.	Turned on front end.*	Advanced 1 inch on hoop.	Advanced to middle of hoop.	On entire surface of hoop.	In Johnson pump turned on.	Turned off.	Water running on hoop.	Hoop cooling.	Pressure applied.		
	Sec.	*Sec.*	*Min.*	*Min.*	*Min.*	*Min.*	*Min.*	*Sec.*	*Sec.*	*Sec.*	*Min.*	*Min.*	*Min.*	*Min.*	*Min.*	*Min.*	*Min.*	*Min.*	*Min.*	*Min.*		*Cu. ft.*
A_1	I	21 min.	38	[Maximum wire did not enter.]	40	2	40	60	45	Lost.	....	6	9	11	12	Not employed.	43	37	44	42¼	See remarks.	220
A_2	45	90	23½		27½	4	27½	60	60	60	2⅝	6½	9½	11½	13		35½	29	36½	34¾	....do	275
A_3	I	13	22½		23½	1	23½	50	10	90	Not taken	8	9⅞	10⅞	12⅜		36¾	28¾	38	36½	... do	211
A_4	10	20	16¾		18½	1½	18½	55	40	60	2¾	6⅝	8⅝	10⅝	11⅝	18¾	29¾	23	30¾	29	Brown.	200
A_5	10	20	16		17½	1¼	17½	60	40	70	2⅝	5¾	6⅞	8⅝	9⅝	17⅝	23⅝	18	24¼	33	... do	200
A_6	10	20	22		22	0	22	55	30	60	3½	6½	7	8	8½	15	22	15½	23	21½	....do	191
A_7	10	20	21		22	1	22	55	30	60	4	7	9	14	15	14	20	13	21	19½	....do	191
A_8	10	20	19		20	1	20	20	65	70	5¾	8	10	11	12	18	34½	26½	35	33½	....do	191
B_1	10	35	16		18	2	18	70	5	125	6½	7⅝	8⅝	9⅝	10½	Not employed.	28½	20½	29½	31½	....do	285
Trunnion B_2	5	30	32 V 42½ H		46½	14½ V 4 H	46½	85	† 135	135	5¾	12¼	13¼	15¾	17¼		51¼	39	52¾	54	See remarks.	610
B_3	5	10	17		19½	2½	19½	60	60	65	3¾	7¾	8¾	10¾	11¾		27¾	20	28¾	27¾	Brown.	225
B_4	5	20	18		19	1	19	80	10	110	2⅝	8⅛	8⅝	*9⅛	10⅝		25⅝	19⅛	27	25¾	....do.	250
B_5	5	10	18		20	2	20	30	10	130	3	6½	7½	8½	9½		25⅛	19	26	25⅝	(?)	240
B_6	5	10	33		34	1	34	30	20	110	3	7⅝	8⅝	10⅝	12⅝	13⅝	31⅝	24	22	31⅝	(?)	260

I=Immediately
V=Vertical diameter.
H=Horizontal diameter.
*=Time required for hoop to clamp body estimated.
†=B_2 had to be rotated, which delayed application.

REMARKS ON THE OPERATIONS OF HOOPING.

Row A.

Pressure was always gradually applied at first as the hoop cooled. The collar brought the hoop to a firm bearing at once, and just about the instant of clamping the full power of the 95-ton hydraulic jack was exerted and kept at full pressure until the hoop was cold.

Hoop A_1.—At the beginning of the heating only one-third of the gas pressure was on—full pressure let on at 9.48 a. m. This hoop was heated somewhat unequally; the top and bottom were hotter than the sides, due to the upward draft caused by the rapid rising of the heated air, which resulted in a current that deflected the flames from the burners at the sides, so that they did not strike the hoop incessantly. At 10.02 a. m. the color of the heated hoop was purple above and brown at the sides; at 10.03 it was purple at the bottom; at 10.06 a. m., when the minimum wire entered, the bottom showed a blue color. This part of the hoop had the highest temperature.

Hoop A_2.—At 11.40 a. m., color of hoop light brown; at 11.41 a. m., blue at top; at 11.43 a. m., dark brown; at 11.46 a. m., brown with purple spots. At 12.07 p. m., shut off water from sprinkler for one minute, and at 12.12 shut off water for one-half minute, to prevent too rapid cooling. Water was turned on preceding hoop A_1 at 11.52 a. m. to prevent it becoming heated from contact with A_2.

Hoop A_3.—The colors of this hoop were about the same as those of A_2. At 2.52 water in sprinkler shut off for 10 seconds; at 2.59½ for 30 seconds; and shut off again at 3.02. At 3.03 water turned on left side only; at 3.04 turned on over entire hoop. At 3.05 the water was shut off for 1 minute, and again at 3.08 for 2½ minutes.

NOTE.—The temperature of the three hoops A_1, A_2, and A_3 were higher than would have been necessary to expand them for the shrinkages corresponding to their own proper diameters. The extra heating was rendered imperative in order to expand them sufficiently to go over a slight fillet turned on the body of the mortar upon the rear of the zone corresponding to A_3. This fillet was turned to fit a corresponding groove accidentally cut on the interior of A_3. This groove was nearly an inch in length, and extended around the interior cylindrical surface of the hoop.

Hoop A_4.—Water turned on preceding hoop (A_3) at 3.59 p. m., to prevent its becoming heated by contact with A_4. The water was turned off A_4 at 4.19 p. m. for 2 minutes, and at 4.23 p. m. for 2 minutes, to prevent too rapid cooling. It was found that the cast-iron pressure collar or ring became heated through by its contact with the heated hoop. To keep this ring cool a Johnson hand force-pump was used, and the stream of water directed around the rear face of the ring and upon the surface of the mortar under and in rear of it.

Began using Johnson pump at 4.15 p. m. Water hoop or sprinkler required 45 seconds for its removal after hoop was cold.

Hoop A_5.—Water turned on A_4 at 5.04¼ p. m. Johnson pump on at 5.18 p. m. At 5.21 p. m. water shut off for 2 minutes.

Hoop A_6.—This hoop was put on after dark, and the city use of the gas diminished the pressure considerably, and required a longer time to heat the hoop. Water turned on A_5 at 7.41½ p. m. Johnson pump used at 7.53 p. m. Shut off water $7^{h}.53^{m}.40^{s}$. for ½ minute, and at 7.57 p. m. for 1⅓ minutes. Water hoop removed in 45 seconds.

Hoop A_7.—Water turned on A_6 at 8.45 p. m. Johnson pump used at 8.55 p. m. Water hoop removed in 45 seconds.

Hoop A_8.—Water turned on A_7 at $9^h.45^m.10^s$. p. m. Johnson pump used at $9^h.57^m.30^s$. p. m. As this hoop is not over the bore, it did not cool as quickly as the other hoops. The pressure ring and breech of mortar increased so rapidly in temperature that water from a larger hose was turned on the breech at 10.08 p. m. Water all turned off at 10.15 p. m. Pressure collar removed at 10.16 p. m. Water turned on cast-iron breech at 10.17 p. m. for 2 minutes.

Hooping (Row A) finished at 10.20 p. m. The water in the bore did not assist perceptibly in cooling the hoop, as the latter was in rear of the chamber.

Row B.

Hoop B_1.—A few of the gas burners were found to be stopped up, but it was not discovered until after the gas was lighted. No serious trouble was caused by it.

Hoop B_2, Trunnion.—The sections on the gas-heater carrying the burners were changed for this hoop on account of its greater length. Sections carrying four burners were substituted for those having three burners. This hoop was suspended in the heater with the axis of the trunnions vertical, and the weight being greater in the vertical line caused the hoop to assume a slight ellipticity with the transverse axis vertical; hence the minimum wire entered vertically long before it would enter horizontally. This hoop was heated somewhat unequally, due partly to its circumferential asymmetry and partly to the influence of the currents of air in the foundry. One segment least exposed to air-currents was heated until the oxidized surface showed a bright purple color; the other segments showed either straw-color, brown, or purple. The trunnions were not heated to as high a temperature as was anticipated, showing a variation from faint straw-color to brown. Every effort was made to keep them at as low a temperature as possible, and with reasonable success.

Trunnion hoops should have a slight cylindrical projection left on the end of one trunnion, into which a hole may be tapped for an eye-bolt, by which to suspend the hoop in the gas-heater, otherwise it is an awkward piece to handle. This projection should be about 2 inches in diameter and 1.5 inch long, and have its axis coincident with that of the trunnion.

Hoop B_3.—No remarks.

Hoop B_4.—The temperature of this hoop was lower than that of B_3. Color varying from faint straw to brown. The gun was slightly warm in rear of this hoop.

Hoop B_5.—Heated little longer than B_4, and turned on water a little too soon. Slight explosions were heard at bottom, which showed that the water penetrated between hoops and reached body of gun, where being confined and converted into steam caused the spluttering sounds heard in its efforts to escape. This showed that too short a time had been allowed before turning on the water, and that the hoop had not firmly clamped the gun. Warmth just perceptible in rear of hoop. Color of hoop uncertain; observers not accustomed to tempering steel by the electric light, and could not judge of the color displayed by the heated hoop.

Hoop B_6.—The day being cloudy, and darkness coming on early, the city began using gas about the time this hoop was placed in the heater, which diminished the pressure of gas very perceptibly, and required longer time to heat hoop. Color uncertain—supposed to be brown. The variable intensity of the electric light used to illuminate the building forbade any attempt to study colors on the steel with any satisfaction or any degree of certainty. In 7 minutes after B_6 was in position the rear face of Hoop A_8 showed a perceptible increase of temperature.

Throughout the hooping, each hoop and the gun was allowed to get cold before another hoop was put on.

The pressure-collar or ring used with Row A to bring the face of the hoop to a firm bearing and keep the joints close was found to be a little too light. The portions of the ring 90 degrees distant from the points of application of the tension bars of the press had not thickness enough to give proper rigidity at these points, and the consequence was that the rings sprang back slightly, allowing the joints between the hoops to show a greater opening at the top and bottom than at the sides where the pressure was applied.

For Row B a heavier collar was cast, which diminished this effect, but did not wholly counteract it.

Before placing a hoop in the gas-heater care should be taken to ascertain whether the burners are all free from obstructions. This is easily accomplished by turning on the blast and passing the hand rapidly over the orifices of the burners. An impinging current of air will be felt if the burner be clear.

It was impracticable on account of the interposition of the pressure ring to observe the instant when the hoops clamped the body of the mortar. Therefore, the time required for the hoop to cool sufficiently to clamp the piece was estimated, using the known data obtained from observations on the experimental cylinder for arguments. The estimated time for clamping was assumed to vary from five to eight minutes, depending on the expansion obtained, the temperature of the hoop, and the time elapsing from extinguishing the gas until the hoop was in position on the mortar.

A longer time was required for clamping in the trials with the experimental cylinder; but, in the actual hooping the hoops were put on at a lower temperature, the volume of water passing through the bore was relatively greater and had a lower temperature, and the surfaces of contact* with rapidly conducting materials were greater; hence, it was estimated that the cooling of the hoops would be more rapid, and that less time would be required for clamping.

Joints or spaces between hoops after shrinking on. Row A.

After the first row of hoops (row A) was on the mortar and had remained at rest 16 hours, the openings between the several hoops due to the shrinking away of the metal were measured with standard slips of brass varying in thickness by one-thousandth of an inch.

The thicknesses of these slips were verified immediately afterward by measurements made with small vernier calipers, fitted with a micrometer screw. It was found in some cases that the opening inside was less than that on the exterior. The first hoop, A, showed an opening at the top and bottom, between the hoop and the cast-iron shoulder of the body, but at the sides directly beneath the points of application of the longitudinal iron bars, which transmitted the pressure directly from the hydraulic jack to the pressure collar in rear of the hoop, no opening was present that could be measured. The relatively large opening above noted was due to two causes: (1) To the curved shoulder on the cast-iron body which wedged off the hoop, as it were, when it contracted in shrinking on; (2) to the springing back of the cast-iron retaining collar or ring at the points most distant from the points of application of the pressure, where it was supported only by its own rigidity.

---

* The interior and both faces of each hoop were in contact with cold metallic surfaces.

Width of spaces between hoops of row A after shrinking on.

Between—	Opening, width of.	Kind of gauge, tight or loose.	Remarks.
	"		
Cast-iron shoulder and A_1	.008	Tight at top	Joint closed at sides where pressure applied.
A_1 and A_2	.000		No joint visible; closed all around.
A_2 and A_3	.003	Easy gauge	Slip inserted 3".
A_3 and A_4	.002	Easy for 5 inches	.''003-slip entered .''25
A_4 and A_5	.002	In 4 inches	.''003-slip entered exterior slightly.
A_5 and A_6	.003	Tight	
A_6 and A_7	.003	Loose	Tight at top.
A_7 and A_8	.003	Tight	Tight at top with .''002 slip.

Joints or spaces between hoops after shrinking on. Row B.

Between—	Depths to which the gauges were inserted at the—									
	Top.					Bottom.				
	Thickness of brass gauges.					Thickness of brass gauges.				
	.''002	.''0035.	.''004.	.''005.	.''002.	.''0035.	.''004.	.''005.	.''006.	.''0085.
	In.	*In.*	*In.*	*In.*	*In.*	*In.*	*In*	*In.*	*In.*	*In.*
A_1 and B_1	0.75	0.6		0.4 tight				0.6		
B_1 and B_2 trunnion	1.00	0.2 tight				2.5	2.25	2.25	1.25	0.1*
B_2 and B_3				0.9 tight				2.8		0.1
B_3 and B_4	1.5	0.4		0.2		2.25	0.75	0.25		
B_4 and B_5	0.25	0.05			0.75 loose	0.25				
B_5 and B_6	Tight joint corner of .''002-slip barely engaged.				1.25	0.75	0.5	0.1		

* At side where pressure applied .''005 gauge inserted 0''.8.

SUMMARY FOR ROW B.

Between—	Maximum openings between hoops.	
	At top.	At bottom.
	Inches.	*Inches.*
A_1 and B_1	.005	.005
B_1 and B_2 trunnion	.0035	.0085
B_2 and B_3	.005	.0085
B_3 and B_4	.005	.005
B_4 and B_5	.0035	.0035
B_5 and B_6	No opening.	.005

COLOR AND TEMPERATURE.*

The temperatures of the hoops and their approximate expansion were estimated from the color of the film of oxide on the surface of the steel. The trials with the experimental cylinder showed that with this quality of steel a uniform *brown* color indicated a temperature that gave sufficient expansion of the hoop, without exceeding the maximum limit. The color test was used in conjunction with the measuring points to determine the expansion.

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* For table of color, &c., see Appendix XV, Table 53.

This test is especially valuable in determining the uniformity of the heating of the different parts of the same hoop. The variations or shades of color indicate like variations in temperature. It is also of value in determining approximately the instant when the hoop should first be swung clear of the gas flames for a trial test of the expansion, thus not only saving labor, but expediting the heating of the hoop by not having to remove it from the flames so frequently for trial measurements with the expansion rods.

Attention to the colors exhibited by the different parts of the hoop will readily indicate to the observer the hottest points and the effect of currents of air in the foundry.

This reference to the color test presupposes that the observer has had experience in tempering various qualities of steel.

The brown color aimed at in each of these hoops before removing from the fire is a tolerably easy tint to recognize; and even if the observer pass it he will certainly detect the purple spots which follow further heating. The approximate temperatures (determined by the color test) adopted as limits in heating the hoops were 450° Fah. and 520° Fah.

The condition and the "finish" of the surface affects the purity of the colors exhibited and must be considered in all cases, as well as the quality of the metal.

These hoops were put on at a much lower temperature than has ever before been attempted at this foundry. It was found that with skilled men, well handled, plenty of time existed for getting the hoops in position before they could cool sufficiently to clamp the mortar previous to reaching their prescribed positions.

Statement of fabrication of ordnance for the service of the United States by South Boston Iron Works, at the South Boston Foundry, under the supervision of Capt. D. A. Lyle, Ordnance Department, U. S. A.

[12-inch M. L. R. mortar (hooped with steel), cast March 1, 1884. Inspected November 28, 1884.]

CHARGE.

Iron used.

Grade of iron.	Furnaces.			
	No. 1.	No. 2.	No. 3.	Total.
	Tons.			
No. 1				
No. 2	8	Richmond		8
No. 3, hard*	1	Richmond		1
No. 3, soft	9	Richmond		9
Remelted	9	Section of 15-inch Rodman S. B. gun.		9
	27			27

* Classed here as No. 4, Richmond.

Coal consumed.—Total Pennsylvania gas-coal, 37,140 pounds.

RECORD OF CASTING.

Furnaces fired March 1, 1884, at 4 a. m. Metal down at 11 a. m.

Time of melting, 7 hours.

Time in fusion, 9 hours.

Gun cast at 8 p. m.

Time occupied in casting, 15 minutes.

Temperature of water entering core-barrel, 36 degrees.

Temperature of water leaving core-barrel, 51 degrees.

Rate of water per minute, 20 gallons.

Fire kindled in pit 8.30 p. m.

Fire in pit went out March 3, 5 a. m.

Temperature of pit, not taken.

Temperature of pit, not taken.

Fire in pit burned 32½ hours.

Water shut off March 2 at 10.51 a. m.

Core-barrel removed at 11 a. m.

Water entered gun at 12 m.

Rate of water per minute, 10 gallons.

Temperature of water entering gun, 36 degrees.

Temperature of water leaving gun, 163 degrees.

Rate of water changed March 3 at 10 a. m. to 8 gallons.

Total time in cooling gun, 83½ hours.

COOLING TABLES.

Core-barrel.		Core-barrel removed.									
Hours.	Degress.	Hours.	Degrees.	Hours.	Degrees.	Hours.	Degrees.	Hours.	Degrees.	Hours.	Degrees.
1	67	16	163	31	100	46	48	61	40	76	38
2	66	17	159	32	94	47	47	62	39½	77	38
3	65	18	154	33	86	48	47	63	39½	78	38
4	64	19	149	34	79	49	47	64	39½	79	38
5	63	20	145	35	72	50	46	65	39	80	38
6	61	21	141	36	65	51	46	66	39	81	37½
7	60	22	138	37	60	52	45	67	39	82	37½
8	59	23	133	38	†62	53	44	68	38½	83	37
9	58	24	129	39	60	54	43	69	38	84	(‡)
10	57	25	125	40	58	55	43	70	38	....	......
11	56	26	122	41	56	56	42	71	38	....	......
12	54	27	119	42	54	57	42	72	38	....	......
13	52	28	115	43	52½	58	41	73	38	....	......
14	51	29	112	44	51	59	40½	74	38	....	......
15	(*)	30	106	45	49½	60	40	75	38	....	......

* Water shut off and arbor hoisted; water rate changed to 10 gallons per minute.
† Water rate changed to 8 gallons per minute.
‡ Water shut off at 8 a. m., March 5, and gun hoisted from pit at 3.15 p. m. same date.

MECHANICAL TESTS.

Specific gravity.

Specimen.	How taken.	Density.
No. 1..........	Tangential ...	7.2660
No. 2..........	.. do	7.2740
No. 3..........	....do	7.2514
No. 9..........	....do	7.2550
No. 10..........	... do..........	7.2615
No. 11.	....do	7.2754
"Outside"....	Longitudinal .	7.2155
"Inside"......	....do	7.2595
No. 12....	....do..........	7.2382
No. 13..........	....do..........	7.2685
No. 14..........	....do..........	7.2622
No. 15..........	... do..........	7.2600
No. 16..........	... do..........	7.2471
No. 17..........	....do..........	7.2495

TENSILE STRENGTH.

Specimen.	Diameter of specimen.	Breaking weight.	Tenacity.
No. 1	1. 1999	33, 200	29, 493
No. 2	1. 2	34, 300	80, 328
No. 3	1. 198	35, 800	31, 753
No. 9	1. 198	34, 600	30, 695
No. 10	1. 193	35, 400	31, 669
No. 11	1. 197	36, 000	31, 991
Outside longitudinal	1. 2	28, 300	25, 023
Inside longitudinal	1. 2	31, 400	27, 764

INITIAL TENSION.

Exterior diameter of ring.	Exterior opening.	Circumference of exterior of ring.	Exterior per inch of circumference.	Initial tension.
Inches.	*Inches.*			
22. 375	0. 101	101. 7093	. 000993	15, 750

ADDITIONAL SPECIMENS.

No.	Diameter of specimen.	How taken.	Breaking weight.	Tenacity.
			Pounds.	
12	1. 2	Longitudinal	35, 700	31, 506
13	1. 2	do	35, 300	31, 212
14	1. 2	do	37, 000	32, 715
15	1. 2	do	33, 000	29, 188
16	1. 2	do	33, 900	99, 974
17	1. 2	do	34, 300	30, 328

Record of measurements with star-gauge of body for 12-*inch cast-iron M. L. R. mortar hooped with steel.*

[Finished for reception of steel hoops. Prescribed diameter =11.95 inches.]

Distance from muzzle.	Diameter of bore.		Distance from muzzle.	Diameter of bore.		Distance from muzzle.	Diameter of bore.	
	Horizontal.	Vertical.		Horizontal.	Vertical.		Horizontal.	Vertical.
Inches.	*Inches.*	*Inches.*	*Inches.*	*Inches.*	*Inches.*	*Inches.*	*Inches.*	*Inches.*
2. 2	11. 951	11. 951	51. 5	11. 951	11. 951	77. 8	11. 952	11. 9505
7. 2	11. 951	11. 951	52. 5	11. 951	11. 951	82.	11. 952	11. 9515
12. 2	11. 951	11. 950	53. 5	11. 951	11. 9515	86. 1	11. 952	11. 9505
17. 2	11. 951	11. 950	53. 8	11. 952	11. 9515	86. 3	11. 952	11. 951
22. 2	11. 9515	11. 951	57.	11. 952	11. 952	90.	11. 952	11. 950
27. 2	11. 951	11. 951	60. 4	11. 952	11. 9515	92. 2	11. 947	11. 947
32. 2	11. 9515	11. 951	60. 6	11. 952	11. 951	92. 4*	11. 848	11. 848
37. 2	11. 951	11. 951	64. 8	11. 952	11. 951	93. 6	11. 8485	11. 848
42. 2	11. 951	11. 951	69. 1	11. 952	11. 9515	93. 8	11. 849	11. 8475
47. 2	11. 951	11. 951	69. 3	11. 952	11. 951	97. 9	11. 8495	11. 848
49. 5	11. 952	11. 951	73. 5	11. 9515	11. 9515	102. 1	11. 839	11. 848
50. 5	11. 951	11. 951	77. 6	11. 952	11. 950	102. 3	11. 835	11. 838

* The distance from 92. 4 to 102. 3, both inclusive, are within the chamber.

Diameters, compressions, and extensions of bore of

[Table showing diameters of bore of 12-inch M. L. R. mortar before hooping, after application of Rows of the bore due to the application of Row A, Row B, and both rows, together with

Under hoop.	Distance from muzzle.	Diameter of bore ready for hooping, &c.							
		Before hooping. (*a*)		After application Row A. (*b*)		After application Row B. (*c*)		After finishing exterior Row B. (*d*)	
		H.	V.	H.	V.	H.	V.	H.	V.
	In.	*Inches.*	*Inches.*	*Inches.*	*Inches.*	*Inches.*	*Inches.*	*Inches.*	*Inches.*
Cylinder in front of hoops	49.5	11.952	11.951	11.949	11.948	11.9485	11.948	11.949	11.950
	50.5	11.951	11.951	11.948	11.948	11.948	11.9475	11.949	11.948
	51.5	11.951	11.951	11.947	11.9475	11.947	11.947	11.948	11.9475
	52.5	11.951	11.951	11.947	11.947	11.947	11.9465	11.948	11.947
	53.5	11.951	11.9515	11.947	11.9465	11.947	11.946	11.946	11.947
Shoulder in front of hoops:									
A_1 Front end	53.8	11.952	11.9515	11.946	11.946	11.946	11.946	11.946	11.946
A_1 Middle	57.	11.952	11.952	11.945	11.945	11.945	11.944	11.945	11.944
A_1 Rear end	60.4	11.952	11.9515	11.9445	11.944	11.943	11.941	11.943	11.942
A_2 Front end	60.6	11.952	11.951	11.944	11.944	11.941	11.944	11.943	11.941
A_2 Middle	64.8	11.952	11.951	11.943	11.943	11.937	11.938	11.940	11.938
A_2 Rear end	69.1	11.952	11.9515	11.943	11.943	11.938	11.936	11.938	11.936
A_3 Front end	69.3	11.952	11.951	11.945	11.943	11.937	11.936	11.938	11.936
A_3 Middle	73.5	11.9515	11.9515	11.943	11.943	11.937	11.935	11.937	11.935
A_3 Rear end	77.6	11.952	11.950	11.943	11.942	11.936	11.935	11.937	11.935
A_4 Front end	77.8	11.952	11.9505	11.943	11.943	11.937	11.935	11.937	11.935
A_4 Middle	82.	11.952	11.9515	11.943	11.9425	11.937	11.934	11.937	11.935
A_4 Rear end	86.1	11.952	11.9505	11.943	11.943	11.937	11.9355	11.937	11.935
A_5 Front end	86.3	11.952	11.951	11.9435	11.9435	11.937	11.935	11.937	11.935
A_5 Middle	90.	11.952	11.950	11.943	11.943	11.936	11.9355	11.936	11.9355
A_5	*92.2	11.947	11.947	11.938	11.938	11.932	11.933	11.9325	11.931
A_5 Chamber.	†92.4	11.848	11.848	11.8365	11.838	11.832	11.830	11.833	11.832
A_5 Rear end	93.6	11.8485	11.848	11.838	11.838	11.831	11.830	11.833	11.832
A_6 Front end	93.8	11.849	11.8475	11.838	11.838	11.8325	11.829	11.833	11.831
A_6 Middle	97.9	11.8495	11.848	11.838	11.838	11.830	11.829	11.831	11.832
A_6 Rear end	102.1	11.839	11.848	‡	‡	....	....	....	....
	102.3	11.835	11.838	‡	‡	....	....	....	....

* In front of shoulder.

† In rear of shoulder.

‡ After application of the hoops, on account of the compression of bore, it was impossible to measure this diameter with the star-gauge points used in measuring the rest of the chamber. At 101.4 inches from muzzle, the farthest point to which the star-gauge could be inserted, the diameters were: horizontal, 11.837 inches; vertical, 11.832 inches.

12-inch *M. L. R. mortar as affected by the hooping.*

A and B, after finishing exterior of Row B, after finish-boring, and after rifling; also, the compressions the extensions of the bore due to finishing the exterior of Row B and to rifling.

Distance from muzzle.	Diameters of finished bore.			Compression of bore due to—						Extension of bore due to—			
	After boring to prescribed finished diameter. (e)		After rifling (across lands). (f)	Application of Row A. (a—b)		Application of Row B. (b—c)		Application of both rows. (Total.) (a—c)		Finishing of exterior of Row B. (c—d)		Rifling. (e—f)	
	H.	V.		H.	V	H.	V.	H.	V.	H.	V.	H.	V.
In.	Inches.	Inches.	Inches.	Inches.	Inches	Inches.	Inches.	Inches.	Inches.	Inches.	Inches.	In.	Inches.
49	11.9995	11.998	11.9985	.003	.003	.0005	.000	.0035	.003	.0005	.001	.001	+.0005
50	11.999	11.998	11.998	.003	.003	.000	.0005	.003	.0035	.001	.0005	.001	.000
51	11.998	12.000	11.998	.004	.0035	.000	.0005	.004	.004	.001	.0005	.000	.002
52	11.998	11.998	11.998	.004	.004	.000	.0005	.004	.0045	.001	.0005	.000	.000
53	11.999	11.998	11.999	.004	.005	.000	.0005	.004	.0055	+.001	.001	.000	+.001
54	11.9985	11.9975	11.9985	.006	.0055	.000	.000	.006	.0055	.000	.000	.000	+.001
57	11.998	11.9985	11.998	.007	.007	.000	.001	.007	.008	.000	.000	.000	.0005
60	11.998	11.998	11.998	.0075	.0075	.0015	.003	.009	.0105	.000	.001	.000	.000
63	11.998	11.998	11.998	.008	.007	.003	.000	.011	.007	.002	+.000	.000	.000
66	11.998	11.998	11.998	.009	.008	.006	.005	.015	.013	.003	.000	.000	.000
[illegible]	11.998	11.999	11.998	.009	.0085	.005	.007	.014	.0155	.000	.000	.000	.001
[illegible]	11.998	11.999	11.998	.007	.008	.008	.007	.015	.015	.001	.000	.000	.001
[illegible]	11.998	11.999	11.998	.0085	.0085	.006	.008	.0145	.0165	.000	.000	.000	.001
77	11.998	11.999	11.998	.009	.008	.007	.007	.016	.015	.001	.000	.000	.001
[illegible]	11.998	11.999	11.998	.009	.0075	.006	.008	.015	.0155	.000	.000	.000	.001
[illegible]	11.998	11.999	11.997	.009	.0090	.006	.0085	.015	.0175	.000	.001	.001	.002
[illegible]	11.998	11.999	11.998	.009	.0075	.006	.0075	.015	.0150	.000	+.0005	.000	.001
87	11.998	11.999	11.998	.0085	.0075	.0065	.0085	.015	.016	.000	.000	.000	.001
[illegible]	11.998	11.999	11.998	.009	.007	.007	.0075	.016	.0145	.000	.000	.001	.001
[illegible]	11.991	11.994	....	.009	.009	.006	.005	.015	.014	.0005	+.002	...	....
[illegible]	11.991	11.994	....	.0115	.010	.0045	.008	.016	.018	.001	.002	...	....
[illegible]	11.849	11.849	....	.0105	.010	.007	.008	.0175	.018	.002	.002	...	....
94	11.848	11.849	....	.011	.0095	.0055	.009	.0165	.0185	.0005	.002	...	....
[illegible]	11.847	11.848	....	.0115	.010	.008	.009	.0195	.019	.001	.003	...	....
102	11.8465	11.843	....	....	....	....	....	....	....	....	....	...	....
[illegible]	....	....	....	....	....	....	....	....	....	....	....	...	....

Record of measurements with star gauge of the finished bore, after rifling, of 12″ M. L. R. mortar, hooped with steel.

[Prescribed diameter = 12″.]

Distance from muzzle.	After rifling.		Distance from muzzle.	After rifling.		Distance from muzzle.	After rifling.		Distance from muzzle.	After rifling.	
	Across lands.	Across grooves.		Across lands.	Across grooves.		Across lands.	Across grooves.		Across lands	Across grooves.
1	11.999	12.117	24	11.998	12.118	47	11.908	12.117	70	11.998	12.116
2	11.999	12.117	25	11.998	12.117	48	11.998	12.116	71	11.998	12.116
3	11.999	12.117	26	11.998	12.117	49	11.9985	12.116	72	11.998	12.116
4	11.999	12.117	27	11.998	12.117	50	11.908	12.116	73	11.998	12.116
5	11.999	12.117	28	11.998	12.117	51	11.998	12.116	74	11.998	12.116
6	11.999	12.117	29	11.998	12.117	52	11.998	12.116	75	11.997	12.116
7	11.999	12.117	30	11.998	12.117	53	11.909	12.116	76	11.998	12.116
8	11.999	12.118	31	11.998	12.117	54	11.9985	12.116	77	11.998	12.116
9	11.998	12.119	32	11.998	12.117	55	11.999	12.116	78	11.998	12.116
10	11.908	12.120	33	11.998	12.117	56	11.998	12.1165	79	11.998	12.116
11	11.998	12.118	34	11.998	12.117	57	11.998	12.1165	80	11.998	12.116
12	11.998	12.117	35	11.999	12.117	58	11.998	12.116	81	11.997	12.117
13	11.998	12.118	36	11.998	12.118	59	11.998	12.116	82	11.997	12.116
14	11.998	12.118	37	11.998	12.117	60	11.998	12.116	83	11.998	12.116
15	11.999	12.118	38	11.998	12.117	61	11.998	12.116	84	11.998	12.116
16	11.999	12.116	39	11.998	12.117	62	11.998	12.116	85	11.998	12.117
17	11.999	12.116	40	11.998	12.117	63	11.998	12.116	86	11.998	12.118
18	11.998	12.117	41	11.999	12.117	64	11.998	12.116	87	11.998	12.118
19	11.999	12.118	42	11.9985	12.117	65	11.998	12.116	88	11.998	12.116
20	11.998	12.118	43	11.998	12.117	66	11.998	12.116	89	11.998	12.117
21	11.998	12.117	44	11.998	12.117	67	11.9975	12.117	90	11.998	12.117
22	11.998	12.118	45	11.998	12.117	68	11 998	12.117	90.25	11.997	12.117
23	11.998	12.118	46	11.998	12.118	69	11.998	12.117			

RIFLING.

Depths of grooves in finished bore of 12″ M. L. R. mortar, hooped with steel, showing differences between the diameters of the bore measured across lands and grooves.

[Prescribed diameter = 12″. Depth of grooves, max. = ″.065; min. = ″.060.]

Distance from muzzle.	Difference.	Depth of grooves.	Distance from muzzle.	Difference.	Depth of grooves.	Distance from muzzle.	Difference.	Depth of grooves.	Distance from muzzle.	Difference.	Depth of grooves.
	Inches.	*Inches.*		*Inches.*	*Inches.*		*Inches.*	*Inches.*		*Inches.*	*Inches.*
1	.118	.059	24	.120	.060	47	.119	.0595	70	.118	.059
2	.118	.059	25	.119	.0595	48	.118	.059	71	.118	.059
3	.118	.059	26	.119	.0595	49	.1175	.05875	72	.118	.059
4	.118	.059	27	.119	.0595	50	.118	.059	73	.118	.059
5	.117	.0585	28	.119	.0595	51	.118	.059	74	.118	.059
6	.118	.059	29	.119	.0595	52	.118	.059	75	.119	.0595
7	.118	.059	30	.119	.0595	53	.117	.0585	76	.118	.059
8	.119	.0595	31	.119	.0595	54	.1175	.05875	77	.118	.059
9	.121	.0605	32	.119	.0595	55	.117	.0585	78	.118	.059
10	.122	.061	33	.119	.0595	56	.1185	.05925	79	.118	.059
11	.120	.060	34	.119	.0595	57	.1185	.05925	80	.118	.059
12	.119	.0595	35	.118	.0595	58	.118	.059	81	.120	.060
13	.120	.060	36	.120	.060	59	.118	.059	82	.119	.0595
14	.120	.060	37	.119	.0595	60	.118	.059	83	.118	.059
15	.119	.0595	38	.119	.0595	61	.118	.059	84	.118	.059
16	.117	.0585	39	.119	.0595	62	.118	.059	85	.119	.0595
17	.117	.0585	40	.119	.0595	63	.118	.059	86	.120	.060
18	.119	.0595	41	.118	.059	64	.118	.059	87	.120	.060
19	.119	.0595	42	.1185	.05925	65	.118	.059	88	.118	.059
20	.120	.060	43	.119	.0595	66	.118	.059	89	.119	.0595
21	.119	.0595	44	.119	.0595	67	.1195	.05975	90	.119	.0595
22	.120	.060	45	.119	.0595	68	.119	.0595	90.25	.120	.060
23	.120	.060	46	.120	.060	69	.119	.0595			

Verification of ordinates of guide-plate for rifling curve for 12″ M. L. R. mortar as measured from the rifling machine.

[Origin of abscissas = 19″ from bottom of bore.]

Distance from origin of abscissas.	Prescribed length of ordinates.	Actual length.	Actual variation.	Remarks.	Distance from origin of ordinates.	Prescribed length of ordinates.	Actual length.	Actual variation.	Remarks.
Inches.	*Inches.*	*Inches.*	*Inches.*		*Inches.*	*Inches.*	*Inches.*	*Inches.*	
0	0	0	0	19″ from bottom of bore.	54	2.99	2.995	+.005	
6	.21	.21	0		60	3.41	3.43	+.02	
12	.46	.44	—.02		66	3.88	3.91	+.03	
18	.74	.73	—.01		72	4.37	4.38	+.01	
24	1.04	1.02	—.02		78	4.87	4.87	0	
30	1.38	1.36	—.02		84	5.38	5.38	0	
36	1.74	1.78	+.04		88	5.74	5.73	—.01	
42	2.13	2.13	0		91.5	6.06	6.055	—.005	At muzzle.
48	2.54	2.56	+.02						

Table showing exterior diameters of 12-inch M. L. rifled mortar (finished).

Subject of measurement.	Distance from muzzle.	Exterior diameters.	Subject of measurement.	Distance from muzzle.	Exterior diameters.	Subject of measurement.	Distance from muzzle.	Exterior diameters.
	Inches.	*Inches.*		*Inches.*	*Inches.*		*Inches.*	*Inches.*
Chase ...	1.	22.542	B_2	80	42.45	B_4	98	41.505
Cylindrical .. }	49.5	32.538		81	42.45	B_5	99	41.500
Shoulder..... }	53.5	32.532	B_3	82	41.5		100	41.502
A_1	57.0	37.1		83	41.514		101	41.504
B_1	63.5	41.00		84	41.5		102	41.511
	66.5	41.01		85	41.507		103	41.506
B_2 (trunnion)..	68	42.45		86	41.508		104	41.500
	69	42.45		87	41.504		105	41.500
	70	42.45		88	41.511		106	41.500
	71	42.45		89	41.500	B_6	107	41.500
	72	42.45		90	41.498		108	41.505
	73	42.45	B_4	91	41.500		109	41.509
	74	42.45		92	41.500		110	41.508
	75	42.45		93	41.500		111	41.506
	76	42.45		94	41.498		112	41.505
	77	42.45		95	41.500	A_2............	115.25	35.940
	78	42.45		96	41.500	Body	119	31.039
	79	42.45		97	41.507			

Record of measurements with star gauge of the finished bore, after rifling, of 12" M. L. R. mortar, hooped with steel.

[Prescribed diameter = 12".]

Distance from muzzle.	After rifling.		Distance from muzzle.	After rifling.		Distance from muzzle.	After rifling.		Distance from muzzle.	After rifling.	
	Across lands.	Across grooves.		Across lands.	Across grooves.		Across lands.	Across grooves.		Across lands	Across grooves.
1	11.999	12.117	24	11.998	12.118	47	11.998	12.117	70	11.998	12.116
2	11.999	12.117	25	11.998	12.117	48	11.998	12.116	71	11.998	12.116
3	11.999	12.117	26	11.998	12.117	49	11.9985	12.116	72	11.998	12.116
4	11.999	12.117	27	11.998	12.117	50	11.998	12.116	73	11.998	12.116
5	11.999	12.117	28	11.998	12.117	51	11.998	12.116	74	11.998	12.116
6	11.999	12.117	29	11.998	12.117	52	11.998	12.116	75	11.997	12.116
7	11.999	12.117	30	11.998	12.117	53	11.999	12.116	76	11.998	12.116
8	11.999	12.118	31	11.998	12.117	54	11.9985	12.116	77	11.998	12.116
9	11.998	12.119	32	11.998	12.117	55	11.999	12.116	78	11.998	12.116
10	11.998	12.120	33	11.998	12.117	56	11.998	12.1165	79	11.998	12.116
11	11.998	12.118	34	11.998	12.117	57	11.998	12.1165	80	11.998	12.116
12	11.998	12.117	35	11.999	12.117	58	11.998	12.116	81	11.997	12.117
13	11.998	12.118	36	11.998	12.118	59	11.998	12.116	82	11.997	12.116
14	11.998	12.118	37	11.998	12.117	60	11.998	12.116	83	11.998	12.116
15	11.999	12.118	38	11.998	12.117	61	11.998	12.116	84	11.998	12.116
16	11.999	12.116	39	11.998	12.117	62	11.998	12.116	85	11.998	12.117
17	11.909	12.116	40	11.998	12.117	63	11.998	12.116	86	11.998	12.118
18	11.998	12.117	41	11.999	12.117	64	11.998	12.116	87	11.998	12.118
19	11.999	12.118	42	11.9985	12.117	65	11.998	12.116	88	11.998	12.116
20	11.998	12.118	43	11.998	12.117	66	11.998	12.116	89	11.998	12.117
21	11.998	12.117	44	11.998	12.117	67	11.9975	12.117	90	11.998	12.117
22	11.998	12.118	45	11.998	12.117	68	11 998	12.117	90.25	11.997	12.117
23	11.998	12.118	46	11.998	12.118	69	11.998	12.117			

RIFLING.

Depths of grooves in finished bore of 12" M. L. R. mortar, hooped with steel, showing differences between the diameters of the bore measured across lands and grooves.

[Prescribed diameter = 12". Depth of grooves, max. = ".065; min. = ".060.]

Distance from muzzle.	Difference.	Depth of grooves.	Distance from muzzle.	Difference.	Depth of grooves.	Distance from muzzle.	Difference.	Depth of grooves.	Distance from muzzle.	Difference.	Depth of grooves.
	Inches.	*Inches.*		*Inches.*	*Inches.*		*Inches.*	*Inches.*		*Inches.*	*Inches.*
1	.118	.059	24	.120	.060	47	.119	.0595	70	.118	.059
2	.118	.059	25	.119	.0595	48	.118	.059	71	.118	.059
3	.118	.059	26	.119	.0595	49	.1175	.05875	72	.118	.059
4	.118	.059	27	.119	.0595	50	.118	.059	73	.118	.059
5	.117	.0585	28	.119	.0595	51	.118	.059	74	.118	.059
6	.118	.059	29	.119	.0595	52	.118	.059	75	.119	.0595
7	.118	.059	30	.119	.0595	53	.117	.0585	76	.118	.059
8	.119	.0595	31	.119	.0595	54	.1175	.05875	77	.118	.059
9	.121	.0605	32	.119	.0595	55	.117	.0585	78	.118	.059
10	.122	.061	33	.119	.0595	56	.1185	.05925	79	.118	.059
11	.120	.060	34	.119	.0595	57	.1185	.05925	80	.118	.059
12	.119	.0595	35	.118	.0595	58	.118	.059	81	.120	.060
13	.120	.060	36	.120	.060	59	.118	.059	82	.119	.0595
14	.120	.060	37	.119	.0595	60	.118	.059	83	.118	.059
15	.119	.0595	38	.119	.0595	61	.118	.059	84	.118	.059
16	.117	.0585	39	.119	.0595	62	.118	.059	85	.119	.0595
17	.117	.0585	40	.119	.0595	63	.118	.059	86	.120	.060
18	.119	.0595	41	.118	.059	64	.118	.059	87	.120	.060
19	.119	.0595	42	.1185	.05925	65	.118	.059	88	.118	.059
20	.120	.060	43	.119	.0595	66	.118	.059	89	.119	.0595
21	.119	.0595	44	.119	.0595	67	.1195	.05975	90	.119	.0595
22	.120	.060	45	.119	.0595	68	.119	.0595	90.25	.120	.060
23	.120	.060	46	.120	.060	69	.119	.0595			

BLUES.

1	Light purple	530									570	277								530		277
2	Violet	531							531	277										531		277
3	Blue	530	530-570	277-299					559	293									530	570	277	299
4	Bright blue	545					550	288							545-550	285-290	550	288	545	554	285	290
5	Dark purple	550									550	288								550		288
6	Indigo	550							550	288										550		288
7	True blue	550	550	288																550		288
8	Clear blue	550											550	288						550		288
9	Dark blue	550			550	288	601	316			570	299			600	315	601	316	550	601	288	316
10	Full blue	554			560	293									554-563	290-295	560	293	554	563	290	295
11	Deep blue	560					560	293					560	293						560		293
			and higher.																			
12	Opaque black	570	570	299																570		299
13	Paler blue	590									590	310								590		310
14	Nearly black-blue	600											600	315						600		315
15	Grayish blue verging on black	600			600	315														600		315
16	Still paler blue	610									610	321								610		321
17	Still paler blue with tinge of green	630									630	332								630		332
18	Green	630							630	332										630		332
19	Gray	752							752	400										752		400

REMARKS.—1° Fahr. = $\frac{5}{9}$° Cent.; 1° Cent. = $\frac{9}{5}$° Fahr.; C. = $\frac{5}{9}$ (F. − 32°); F. = $\frac{9}{5}$ C. + 32°.

RECORD OF CASTING.

Furnaces fired March 1, 1884, at 4 a. m. Metal down at 11 a. m.

Time of melting, 7 hours.

Time in fusion, 9 hours.

Gun cast at 8 p. m.

Time occupied in casting, 15 minutes.

Temperature of water entering core-barrel, 36 degrees.

Temperature of water leaving core-barrel, 51 degrees.

Rate of water per minute, 20 gallons.

Fire kindled in pit 8.30 p. m.

Fire in pit went out March 3, 5 a. m.

Temperature of pit, not taken.

Temperature of pit, not taken.

Fire in pit burned 32½ hours.

Water shut off March 2 at 10.51 a. m.

Core-barrel removed at 11 a. m.

Water entered gun at 12 m.

Rate of water per minute, 10 gallons.

Temperature of water entering gun, 36 degrees.

Temperature of water leaving gun, 163 degrees.

Rate of water changed March 3 at 10 a. m. to 8 gallons.

Total time in cooling gun, 83½ hours.

COOLING TABLES.

Core-barrel.		Core-barrel removed.									
Hours.	Degrees.	Hours.	Degrees.	Hours.	Degrees.	Hours.	Degrees.	Hours.	Degrees.	Hours.	Degrees.
1	67	16	163	31	100	46	48	61	40	76	38
2	66	17	159	32	94	47	47	62	39½	77	38
3	65	18	154	33	86	48	47	63	39½	78	38
4	64	19	149	34	79	49	47	64	39½	79	38
5	63	20	145	35	72	50	46	65	39	80	38
6	61	21	141	36	65	51	46	66	39	81	37½
7	60	22	138	37	60	52	45	67	39	82	37½
8	59	23	133	38	†62	53	44	68	38½	83	37
9	58	24	129	39	60	54	43	69	38	84	(‡)
10	57	25	125	40	58	55	43	70	38	....	......
11	56	26	122	41	56	56	42	71	38	...	......
12	54	27	119	42	54	57	42	72	38	....	......
13	52	28	115	43	52½	58	41	73	38	....	......
14	51	29	112	44	51	59	40½	74	38	....	......
15	(*)	30	106	45	49½	60	40	75	38	...	......

* Water shut off and arbor hoisted: water rate changed to 10 gallons per minute.
† Water rate changed to 8 gallons per minute.
‡ Water shut off at 8 a. m., March 5, and gun hoisted from pit at 3.15 p. m. same date.

MECHANICAL TESTS.

Specific gravity.

Specimen.	How taken.	Density.
No. 1	Tangential	7.2660
No. 2	do	7.2740
No. 3	do	7.2514
No. 9	do	7.2550
No. 10	do	7.2615
No. 11	do	7.2754
"Outside"	Longitudinal	7.2155
"Inside"	do	7.2595
No. 12	do	7.2382
No. 13	do	7.2685
No. 14	do	7.2622
No. 15	do	7.2600
No. 16	do	7.2471
No. 17	do	7.2495

TENSILE STRENGTH.

Specimen.	Diameter of specimen.	Breaking weight.	Tenacity.
No. 1	1. 1999	33, 200	29, 493
No. 2	1. 2	34, 300	30, 328
No. 3	1. 198	35, 800	31, 753
No. 9	1. 198	34, 600	30, 695
No. 10	1. 193	35, 400	31, 669
No. 11	1. 197	36, 000	31, 991
Outside longitudinal	1. 2	28, 300	25, 023
Inside longitudinal	1. 2	31, 400	27, 704

INITIAL TENSION.

Exterior diameter of ring.	Exterior opening.	Circumference of exterior of ring.	Exterior per inch of circumference.	Initial tension.
Inches.	*Inches.*			
32. 375	0. 101	101. 7093	. 000993	15, 750

ADDITIONAL SPECIMENS.

No.	Diameter of specimen.	How taken.	Breaking weight.	Tenacity.
			Pounds.	
12	1. 2	Longitudinal	35, 700	31, 506
13	1. 2	do	35, 300	31, 212
14	1. 2	do	37, 000	32, 715
15	1. 2	do	33, 000	29, 188
16	1. 2	do	33, 900	99, 974
17	1. 2	do	34, 300	30, 328

Record of measurements with star-gauge of body for 12-*inch cast-iron M. L. R. mortar hooped with steel.*

[Finished for reception of steel hoops. Prescribed diameter =11.95 inches.]

Distance from muzzle.	Diameter of bore.		Distance from muzzle.	Diameter of bore.		Distance from muzzle.	Diameter of bore.	
	Horizontal.	Vertical.		Horizontal.	Vertical.		Horizontal.	Vertical.
Inches.	*Inches.*	*Inches.*	*Inches.*	*Inches.*	*Inches.*	*Inches.*	*Inches.*	*Inches.*
2. 2	11. 951	11. 951	51. 5	11. 951	11. 951	77. 8	11. 952	11. 9505
7. 2	11. 951	11. 951	52. 5	11. 951	11. 951	82.	11. 952	11. 9515
12. 2	11. 951	11. 950	53. 5	11. 951	11. 9515	86. 1	11. 952	11. 9505
17. 2	11. 951	11. 950	53. 8	11. 952	11. 9515	86. 3	11. 952	11. 951
22. 2	11. 9515	11. 951	57.	11. 952	11. 952	90.	11. 952	11. 950
27. 2	11. 951	11. 951	60. 4	11. 952	11. 9515	92. 2	11. 947	11. 947
32. 2	11. 9515	11. 951	60. 6	11. 952	11. 951	92. 4*	11. 848	11. 848
37. 2	11. 951	11. 951	64. 8	11. 952	11. 951	93. 6	11. 8485	11. 848
42. 2	11. 951	11. 951	69. 1	11. 952	11. 9515	93. 8	11. 849	11. 8475
47. 2	11. 951	11. 951	69. 3	11. 952	11. 951	97. 9	11. 8495	11. 848
49. 5	11. 952	11. 951	73. 5	11. 9515	11. 9515	102. 1	11. 839	11. 848
50. 5	11. 951	11. 951	77. 6	11. 952	11. 950	102. 3	11. 835	11. 838

* The distance from 92. 4 to 102. 3, both inclusive, are within the chamber.

Diameters, compressions, and extensions of bore of

[Table showing diameters of bore of 12-inch M. L. R. mortar before hooping, after application of Rows of the bore due to the application of Row A, Row B, and both rows, together with

Under hoop.	Distance from muzzle.	Diameter of bore ready for hooping, &c.							
		Before hooping. (a)		After application Row A. (b)		After application Row B. (c)		After finishing exterior Row B. (d)	
		H.	V.	H.	V.	H.	V.	H.	V.
	In.	*Inches.*	*Inches.*	*Inches.*	*Inches.*	*Inches.*	*Inches.*	*Inches.*	*Inches.*
Cylinder in front of hoops	49.5	11.952	11.951	11.949	11.948	11.9485	11.948	11.949	11.950
	50.5	11.951	11.951	11.948	11.948	11.948	11.9475	11.949	11.948
	51.5	11.951	11.951	11.947	11.9475	11.947	11.947	11.948	11.9475
	52.5	11.951	11.951	11.947	11.947	11.947	11.9465	11.948	11.947
	53.5	11.951	11.9515	11.947	11.9465	11.917	11.946	11.946	11.947
Shoulder in front of hoops:									
A1 Front end	53.8	11.952	11.9515	11.946	11.946	11.946	11.946	11.946	11.946
A1 Middle	57.	11.952	11.952	11.945	11.945	11.945	11.944	11.945	11.944
A1 Rear end	60.4	11.952	11.9515	11.9445	11.944	11.943	11.941	11.943	11.942
A2 Front end	60.6	11.952	11.951	11.914	11.944	11.941	11.944	11.943	11.941
A2 Middle	64.8	11.952	11.951	11.943	11.943	11.937	11.938	11.940	[illegible]
A2 Rear end	69.1	11.952	11.9515	11.943	11.943	11.938	11.936	11.938	[illegible]
A3 Front end	69.3	11.952	11.951	11.945	11.943	11.937	11.936	11.938	[illegible]
A3 Middle	73.5	11.9515	11.9515	11.943	11.943	11.937	11.935	11.937	[illegible]
A3 Rear end	77.6	11.952	11.950	11.943	11.942	11.936	11.935	11.937	[illegible]
A4 Front end	77.8	11.952	11.9505	11.943	11.943	11.937	11.935	11.937	[illegible]
A4 Middle	82.	11.952	11.9515	11.943	11.9425	11.937	11.934	11.937	[illegible]
A4 Rear end	86.1	11.952	11.9505	11.943	11.943	11.937	11.9355	11.937	[illegible]
A5 Front end	86.3	11 952	11.951	11.9435	11.9435	11.937	11.935	11.937	[illegible]
A5 Middle	90.	11.952	11.950	11.943	11.943	11.936	11.9355	11.936	[illegible]
A5	*92.2	11.947	11.947	11.938	11.938	11.932	11.933	11.9325	11.931
A5 Chamber.	†92.4	11.848	11.848	11.8365	11.838	11.832	11.830	11.833	[illegible]
A5 Rear end Chamber.	93.6	11.8485	11.848	11.838	11.838	11.831	11.830	11.833	[illegible]
A6 Front end Chamber.	93.8	11.849	11.8475	11.838	11.838	11.8325	11.829	11.833	11.831
A6 Middle Chamber.	97.9	11.8495	11.848	11.838	11.838	11.830	11.829	11.831	[illegible]
A6 Rear end Chamber.	102.1	11.839	11.848	‡	‡	......	......	......	......
Chamber.	102.3	11.835	11.838	‡	‡	......	......	......	......

* In front of shoulder.

† In rear of shoulder.

‡ After application of the hoops, on account of the compression of bore, it was impossible to measure this diameter with the star-gauge points used in measuring the rest of the chamber. At 101.4 inches from muzzle, the farthest point to which the star-gauge could be inserted, the diameters were: horizontal, 11.837 inches; vertical, 11.832 inches.

12-*inch M. L. R. mortar as affected by the hooping.*

A and B, after finishing exterior of Row B, after finish-boring, and after rifling; also, the compressions the extensions of the bore due to finishing the exterior of Row B and to rifling.

Distance from muzzle.	Diameters of finished bore.			Compression of bore due to—						Extension of bore due to—			
	After boring to prescribed finished diameter. (*e*)		After rifling (across lands). (*f*)	Application of Row A. (*a—b*)		Application of Row B. (*b—c*)		Application of both rows. (Total.) (*a—c*)		Finishing of exterior of Row B. (*c—d*)		Rifling. (*e—f*)	
	H.	V.		H.	V.	H.	V.	H.	V.	H.	V.	H.	V.
In.	*Inches.*	*Inches.*	*Inches.*	*Inches.*	*Inches*	*Inches.*	*Inches.*	*Inches.*	*Inches.*	*Inches.*	*Inches.*	*In.*	*Inches.*
49	11.9995	11.998	11.9985	.003	.003	.0005	.000	.0035	.003	.0005	.001	.001	+.0005
50	11.999	11.998	11.998	.003	.003	.000	.0005	.003	.0035	.001	.0005	.001	.000
51	11.998	12.000	11.998	.004	.0035	.000	.0005	.004	.004	.001	.0005	.000	.002
52	11.998	11.998	11.998	.004	.004	.000	.0005	.004	.0045	.001	.0005	.000	.000
53	11.999	11.998	11.999	.004	.005	.000	.0005	.004	.0055	+.001	.001	.000	+.001
54	11.9985	11.9975	11.9985	.006	.0055	.000	.000	.006	.0055	.000	.000	.000	+.001
57	11.998	11.9985	11.998	.007	.007	.000	.001	.007	.008	.000	.000	.000	.0005
60	11.998	11.998	11.998	.0075	.0075	.0015	.003	.009	.0105	.000	.001	.000	.000
61	11.998	11.998	11.998	.008	.007	.003	.000	.011	.007	.002	+.000	.000	.000
64	11.998	11.998	11.998	.009	.008	.006	.005	.015	.013	.003	.000	.000	.000
69	11.998	11.999	11.998	.009	.0085	.005	.007	.014	.0155	.000	.000	.000	.001
70	11.998	11.999	11.998	.007	.008	.008	.007	.015	.015	.001	.000	.000	.001
73	11.998	11.999	11.998	.0085	.0085	.006	.008	.0145	.0165	.000	.000	.000	.001
77	11.998	11.999	11.998	.009	.008	.007	.007	.016	.015	.001	.000	.000	.001
78	11.998	11.999	11.998	.009	.0075	.006	.008	.015	.0155	.000	.000	.000	.001
82	11.998	11.999	11.997	.009	.0090	.006	.0085	.015	.0175	.000	.001	.001	.002
86	11.998	11.999	11.998	.009	.0075	.006	.0075	.015	.0150	.000	+.0005	.000	.001
87	11.998	11.999	11.998	.0085	.0075	.0065	.0085	.015	.016	.000	.000	.000	.001
90	11.999	11.999	11.998	.009	.007	.007	.0075	.016	.0145	.000	.000	.001	.001
92	11.991	11.994	....	.009	.009	.006	.005	.015	.014	.0005	+.002	....	....
92	11.991	11.994	....	.0115	.010	.0045	.008	.016	.018	.001	.002	...	....
93	11.849	11.849	....	.0105	.010	.007	.008	.0175	.018	.002	.002	....	....
94	11.848	11.849	....	.011	.0095	.0055	.009	.0165	.0185	.0005	.002	....	....
98	11.847	11.848	....	.0115	.010	.008	.009	.0195	.019	.001	.003	....	....
102	11.8465	11.843	....	....	......	....	....	....	....	....	....	....	....
103	....	....	....	....	....	....	....	....	......	....	....	....	....

Record of measurements with star gauge of the finished bore, after rifling, of 12″ M. L. R. mortar, hooped with steel.

[Prescribed diameter = 12″.]

Distance from muzzle.	After rifling.		Distance from muzzle.	After rifling.		Distance from muzzle.	After rifling.		Distance from muzzle.	After rifling.	
	Across lands.	Across grooves.		Across lands.	Across grooves.		Across lands.	Across grooves.		Across lands.	Across grooves.
1	11.999	12.117	24	11.998	12.118	47	11.998	12.117	70	11.998	12.116
2	11.999	12.117	25	11.998	12.117	48	11.998	12.116	71	11.998	12.116
3	11.999	12.117	26	11.998	12.117	49	11.9985	12.116	72	11.998	12.116
4	11.999	12.117	27	11.998	12.117	50	11.998	12.116	73	11.998	12.116
5	11.999	12.117	28	11.998	12.117	51	11.998	12.116	74	11.998	12.116
6	11.999	12.117	29	11.998	12.117	52	11.998	12.116	75	11.997	12.116
7	11.999	12.117	30	11.998	12.117	53	11.999	12.116	76	11.998	12.116
8	11.999	12.118	31	11.998	12.117	54	11.9985	12.116	77	11.998	12.116
9	11.998	12.119	32	11.998	12.117	55	11.999	12.116	78	11.998	12.116
10	11.998	12.120	33	11.998	12.117	56	11.998	12.1165	79	11.998	12.116
11	11.998	12.118	34	11.998	12.117	57	11.998	12.1165	80	11.998	12.116
12	11.998	12.117	35	11.999	12.117	58	11.998	12.116	81	11.997	12.117
13	11.998	12.118	36	11.998	12.118	59	11.998	12.116	82	11.997	12.116
14	11.998	12.118	37	11.998	12.117	60	11.998	12.116	83	11.998	12.116
15	11.999	12.118	38	11.998	12.117	61	11.998	12.116	84	11.998	12.116
16	11.999	12.116	39	11.998	12.117	62	11.998	12.116	85	11.998	12.117
17	11.999	12.116	40	11.998	12.117	63	11.998	12.116	86	11.998	12.118
18	11.998	12.117	41	11.999	12.117	64	11.998	12.116	87	11.998	12.118
19	11.999	12.118	42	11.9985	12.117	65	11.998	12.116	88	11.998	12.116
20	11.998	12.118	43	11.998	12.117	66	11.998	12.116	89	11.998	12.117
21	11.998	12.117	44	11.998	12.117	67	11.9975	12.117	90	11.998	12.117
22	11.998	12.118	45	11.998	12.117	68	11.998	12.117	90.25	11.997	12.117
23	11.998	12.118	46	11.998	12.118	69	11.998	12.117			

RIFLING.

Depths of grooves in finished bore of 12″ M. L. R. mortar, hooped with steel, showing differences between the diameters of the bore measured across lands and grooves.

[Prescribed diameter = 12″. Depth of grooves, max. = ″.065; min. = ″.060.]

Distance from muzzle.	Difference.	Depth of grooves.	Distance from muzzle.	Difference.	Depth of grooves.	Distance from muzzle.	Difference.	Depth of grooves.	Distance from muzzle.	Difference.	Depth of grooves.
	Inches.	*Inches.*		*Inches.*	*Inches.*		*Inches.*	*Inches.*		*Inches.*	*Inches.*
1	.118	.059	24	.120	.060	47	.119	.0595	70	.118	.059
2	.118	.059	25	.119	.0595	48	.118	.059	71	.118	.059
3	.118	.059	26	.119	.0595	49	.1175	.05875	72	.118	.059
4	.118	.059	27	.119	.0595	50	.118	.059	73	.118	.059
5	.117	.0585	28	.119	.0595	51	.118	.059	74	.118	.059
6	.118	.059	29	.119	.0595	52	.118	.059	75	.119	.0595
7	.118	.059	30	.119	.0595	53	.117	.0585	76	.118	.059
8	.119	.0595	31	.119	.0595	54	.1175	.05875	77	.118	.059
9	.121	.0605	32	.119	.0595	55	.117	.0585	78	.118	.059
10	.122	.061	33	.119	.0595	56	.1185	.05925	79	.118	.059
11	.120	.060	34	.119	.0595	57	.1185	.05925	80	.118	.059
12	.119	.0595	35	.118	.0595	58	.118	.059	81	.120	.060
13	.120	.060	36	.120	.060	59	.118	.059	82	.119	.0595
14	.120	.060	37	.119	.0595	60	.118	.059	83	.118	.059
15	.119	.0595	38	.119	.0595	61	.118	.059	84	.118	.059
16	.117	.0585	39	.119	.0595	62	.118	.059	85	.119	.0595
17	.117	.0585	40	.119	.0595	63	.118	.059	86	.120	.060
18	.119	.0595	41	.118	.059	64	.118	.059	87	.120	.060
19	.119	.0595	42	.1185	.05925	65	.118	.059	88	.118	.059
20	.120	.060	43	.119	.0595	66	.118	.059	89	.119	.0595
21	.119	.0595	44	.119	.0595	67	.1195	.05975	90	.119	.0595
22	.120	.060	45	.119	.0595	68	.119	.0595	90.25	.120	.060
23	.120	.060	46	.120	.060	69	.119	.0595			

Verification of ordinates of guide-plate for rifling curve for 12″ M. L. R. mortar as measured from the rifling machine.

[Origin of abscissas = 19″ from bottom of bore.]

Distance from origin of abscissas.	Prescribed length of ordinates.	Actual length.	Actual variation.	Remarks.	Distance from origin of ordinates.	Prescribed length of ordinates.	Actual length.	Actual variation.	Remarks.
Inches.	*Inches.*	*Inches.*	*Inches.*		*Inches.*	*Inches.*	*Inches.*	*Inches.*	
0	0	0	. 0	19″ from bottom of bore.	54	2. 99	2. 995	+. 005	
6	. 21	. 21	0		60	3. 41	3 43	+. 02	
12	. 46	. 44	—. 02		66	3. 88	3. 91	+. 03	
18	. 74	. 73	—. 01		72	4. 37	4. 38	+. 01	
24	1. 04	1. 02	—. 02		78	4. 87	4. 87	0	
30	1. 38	1. 36	—. 02		84	5. 38	5. 38	0	
36	1. 74	1. 78	+. 04		88	5. 74	5. 73	—. 01	
42	2. 13	2. 13	0		91. 5	6. 06	6. 055	—. 005	At muzzle.
48	2. 54	2. 56	+. 02						

Table showing exterior diameters of 12-inch M. L. rifled mortar (finished).

Subject of measurement.	Distance from muzzle.	Exterior diameters.	Subject of measurement.	Distance from muzzle.	Exterior diameters.	Subject of measurement.	Distance from muzzle.	Exterior diameters.
	Inches.	*Inches.*		*Inches.*	*Inches.*		*Inches.*	*Inches.*
Chase	1.	22. 542	B_2	80	42. 45	B_4	98	41. 505
Cylindrical	49. 5	32. 538		81	42. 45	B_5	99	41. 500
Shoulder	53. 5	32. 532	B_3	82	41. 5		100	41. 502
A_1	57. 0	37. 1		83	41. 514		101	41. 504
B_1	63. 5	41. 00		84	41. 5		102	41. 511
	66. 5	41. 01		85	41. 507		103	41. 506
B_2 (trunnion)	68	42. 45		86	41. 508		104	41. 500
	69	42. 45		87	41. 504		105	41. 500
	70	42. 45		88	41. 511		106	41. 500
	71	42. 45		89	41. 500	B_6	107	41. 500
	72	42. 45		90	41. 498		108	41. 505
	73	42. 45	B_4	91	41. 500		109	41. 509
	74	42. 45		92	41. 500		110	41. 508
	75	42. 45		93	41. 500		111	41. 506
	76	42. 45		94	41. 498		112	41. 505
	77	42. 45		95	41. 500	A_2	115. 25	35. 940
	78	42. 45		96	41. 500	Body	119	31. 039
	79	42. 45		97	41. 507			

Table showing colors observed in tempering steel, as given by various authorities.

YELLOWS.

Number of tints.	Colors.	Reference scale of temperatures, Fahr.	Bloxam, 1873.		Haswell, 45th ed., p. 643.		Professor Ordway, Mass. Inst. of Tech., 1884.		Clark (*fide* Claude).		Appleton's Cyclop. of App. Mech.		Hartley. Patented scale. 1789. (*Fide* Jeans.)		Encyc. Brit., 9th ed., vol. xiii, p. 353.		Crookes and Röhrig. Treat. of metal, p. 19.		Extreme range of temperatures.			
																			Fahrenheit.		Centigrade.	
			Fahr.	Cent.	F.	C.	F.	C.	F.	C.	F.	C.	F.	C.	F.	C.	F.	C.	From—	To—	From—	To—
1	Very pale yellow	428											430	221	428	220			428	430	220	221
2	Pale yellow	428															428	220		428		220
3	Very bright yellow	430					430	221												430		221
4	Very faint yellow	430			430	221														430		221
5	Very pale straw-yellow	430									430	221			446–455	230–235			430	455	221	235
6	Straw-yellow	430	430–450	221–232									450	232			446	230	430	450	221	232
7	Yellow	437	470	243					437	225									437	470	225	243
8	A shade of darker yellow	444									444	229								444		229
9	Bright straw-yellow	450					450	232												450		232
10	Pale straw color	450			450	232														450		232
11	Golden yellow	464													464–493	240–245	470	243	464	473	240	245
12	Darker straw color	470									470	243								470		243
13	Full yellow	470			470	243							bright. 470	243						470		243
14	Orange	473							473	245										473		245
15	Still darker straw-yellow	490									490	254								490		254
16	Brown-yellow	490	490	254							500	260							490	500	254	260
17	Yellow tinged with purple spots	520									520	271								520		271
	BROWNS AND PURPLES.																					
1	Brown	490			490	254	490	254					490	254	491	255	491	255	490	491	254	255
2	Brown-yellow	490	490	254							500	260			527–536	275–280			490	536	254	280
3	Red	509							509	265										509		265
4	Brown with purple spots	510			510	265	510	265					510	265	510	265	510	265		510		265
5	Brown-purple	510	510	265																510		265
6	Yellow tinged with purple spots	520									520	271								520		271
7	Purple	520	520	271	538	281	530	277					530	277			530	277	520	538	271	281
8	Light purple	530									530	277								530		277
9	Violet	531							531	277										531		277
10	Dark purple	550									550	288								550		288

BLUES.

1	Light purple	530									530	277								530		277
2	Violet	531							531	277										531		277
3	Blue	530	530–570	277–299					559	293									530	570	277	299
4	Bright blue	545					550	288							545–550	285–290	550	288	545	554	285	290
5	Dark purple	550									550	288								550		288
6	Indigo	550							550	288										550		288
7	True blue	550	550	288																550		288
8	Clear blue	550											550	288						550		288
9	Dark blue	550			550	288	601	316			570	299			600	315	601	316	550	601	288	316
10	Full blue	554			560	293									554–563	290–295	560	293	554	563	290	295
11	Deep blue	560					560	293					560	293						560		293
12	Opaque black	570	and higher. 570	299																570		299
13	Paler blue	590									590	310								590		310
14	Nearly black-blue	600											600	315						600		315
15	Grayish blue verging on black	600			600	315														600		315
16	Still paler blue	610									610	321								610		321
17	Still paler blue with tinge of green	630									630	332								630		332
18	Green	630							630	332										630		332
19	Gray	752							752	400										752		400

Remarks.—1° Fahr. = $\frac{5}{9}$° Cent.; 1° Cent. = $\frac{9}{5}$° Fahr.; C. = $\frac{5}{9}$ (F. − 32°); F. = $\frac{9}{5}$ C. + 32°.

LUMINOSITY OF HEATED STEEL.

Clarke* says the luminosity or shades of temperature have been observed by M. Pouillek, by means of an air pyrometer, to be as follows:

Luminosity.	Temperature.	
	Centigrade.	Fahrenheit.
	Degrees.	*Degrees.*
Nascent red	525	977
Dark red	700	1292
Nascent cherry-red	800	1472
Cherry-red	900	1652
Bright cherry-red	1000	1832
Very deep orange	1100	2012
Bright orange	1200	2192
White	1300	2372
"Sweating" white	1400	2552
Dazzling white	1500	2732

Record of inspection and measurements of hooping of 12-inch muzzle-loading rifled mortar, hooped with steel manufactured at South Boston Foundry under contracts dated September 24, 1883, and June 28, 1884.

HOOPS.

Mark or number.	Row.	Mean length.	Mean thickness.	Interior diameters.				
				1st.	2d.	3d.	4th.	Mean.
		Inches.	*Inches.* In place.	*Inches.*	*Inches.*	*Inches.*	*Inches.*	*Inches.* b
1	A	6.999	3.033	30.9957	30.9954	30.9956	30.9955	30.9956
2	A	8.740	2.457	30.9963	30.9954	30.9959	30.9959	30.9959
3	A	8.503	2.454	31.0006	30.9008	30.9982	31.0005	30.9998
4	A	8.504	2.451	30.9967	30.9965	30.9954	30.9957	30.9961
5	A	7.496	2.451	30 9956	30.9959	30.9963	30.9966	30.9961
6	A	8.510	2.451	30.9953	30.9050	30.9151	30.9947	30.9950
7	A	8.503	2.451	30.9948	30.9958	30.9962	30.9957	30.9956
8	A	8.498	2.451	30.9970	30.9972	30.9971	30.9969	30.9970
1	B	7.505	2.526	35.8956	35.8966	35.8965	35.8957	35.8962
2	B	14.000	3.251	35.8947	35.8962	35.8962	35.8944	35.8954
3	B	8.310	2.780	35.8955	35.8956	35.8056	35.8953	35.8955
4	B	8.310	2.780	35.8959	35.8949	35.8951	35.8957	35.8954
5	B	8.311	2.779	35.8966	35.8963	35.8971	35.8969	35.8967
6	B	8.320	2.780	35.8958	35.8953	35.8957	35.8950	35.8955

ZONES TO BE HOOPED.

Mark or number.	Mean exterior diameters.				
	1st.	2d.	3d.	4th.	Mean.
Under—	*Inches.*	*Inches.*	*Inches.*	*Inches.*	*Inches.* a.
A_1	31.0354	31.0343	31.0341	31.0340	31.0344
A_2	31.0334	31.0325	31.0328	31.0337	31.0331
A_3	31.0412	31.0408	31.0411	31.0408	31.0410
A_4	31.0388	31.0381	31.0385	31.0380	31.0384
A_5	31.0382	31.0376	31.0376	31.0379	31.0378
A_6	31.0395	31.0386	31.0391	31.0392	31.0391
A_7	31.0389	31.0378	31.0385	31.0383	31.0384
A_8	31.0402	31 0392	31.0399	31.0394	31.0397
B_1	35.9330	35.9332	35.9328	35.9331	35.9330
B_2 (trunnion)	35.9479	35.9481	35.9477	35.9481	35.9480
B_3	35.9417	35.9393	35.9418	35.9414	35.9411
B_4	35.9414	35.9390	35.9411	35.9412	35.9407
B_5	35.9418	35.9400	35.9419	35.9419	35.9414
B_6	35.9400	35.9381	35.9399	35.9396	35.9394

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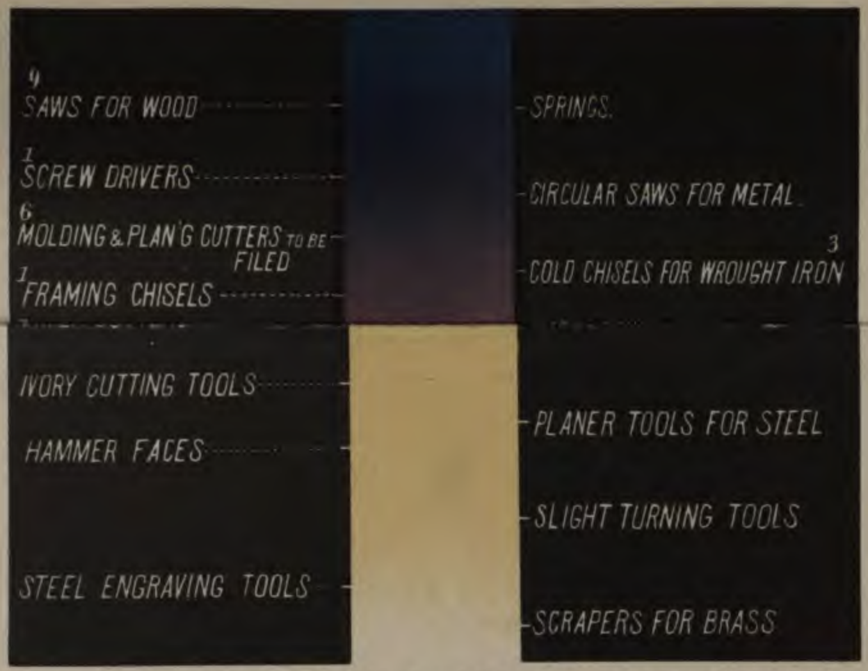
* Clarke's Manual of Rules, Tables, and Data for Mechanical Engineers (1884), p. 328.



As practised by 1. Buck Bros. 2. The Miller Bros Cutlery Co. 3. Brown & Sharpe M'f'g Co. 4. Morse Twist Drill Co. 5. The Pratt & Whitney Co. 6. J. A. Fay & Co. 7. Hoopes & Townsend. 8. Freeland Tool Works. 9. Joshua Oldham. 10. R. Hoe & Co.

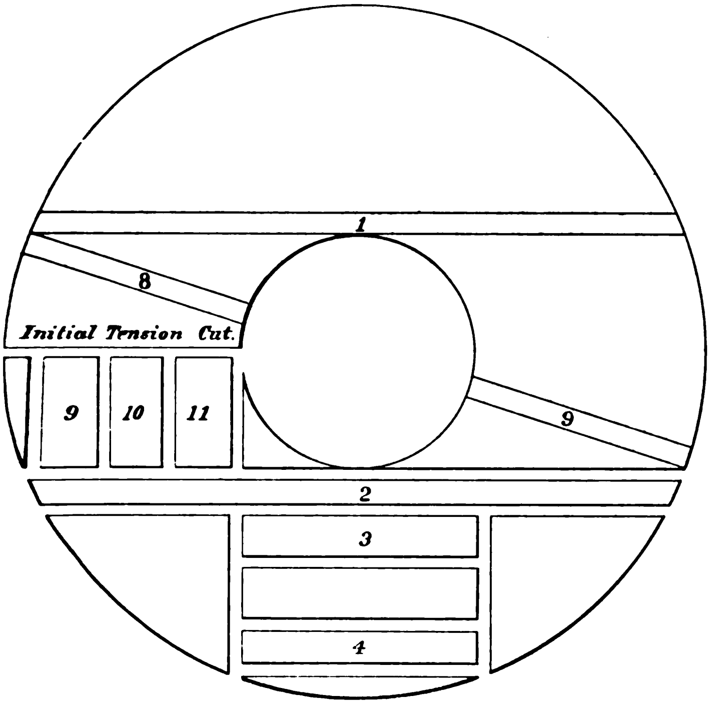
Patented July 2, 1878.

COLOR TEMPERING SCALE.

(See Article on Tempering and Hardening Metals, From Part 5. Appletons "Cyclopaedia of Applied Mechanics".)

H Ex1 pt2 v3 49 1

tial tension ring (2.5 *inches thick*) *taken from cast-iron body of experimental cylinder from* 12-*inch M. L. rifled mortar.*



AFTER UNHOOPING.

INITIAL TENSION.

termined from the two disks noted above. For details see page 483, Report of Chief of Ordnance, 1884.]

	Pounds.
fore hooping	**15,750**
er unhooping	**12,000**

Physical properties of the Midvale steel hoops.*

Hoop.	Length of specimen.	Elastic limit per square inch.	Elastic extension.	Tensile strength per square inch.	Elongation after rupture.	Contraction of area.
	Inches.	*Pounds.*	*Inches.*	*Pounds.*	*Per cent.*	*Per cent.*
Ax..	6	63,000	.002033	115,200	13.0	27.6
	6	59,000	.001883	112,600	12.3	27.6
	3	63,000	.002200	112,000	18.3	32.5
	3	60,000	.001867	111,870	15.7	26.4
	6	65,000	.002183	112,080	12.67	24.4
	6	63,000	.002150	110,800	12.67	27.6
	*(?)	60,000	.001990	Compression specimen.		
Bx..	6	68,000	.002033	117,600	8.9	33.6
	6	65,000	.002067	112,000	15.3	39.2
	3	71,000	.002467	116,460	16.0	35.4
	3	64,000	.002000	112,650	16.0	29.3
	6	57,000	.001867	108,440	10.5	33.6
	6	67,000	.002250	114,000	12.8	30.8
	*(?)	55,000	.001770	Compression specimen.		

The information given in this table was kindly furnished by Lieut. F. E. Hobbs, Ordnance Depart nt, U. S. A.

Report of inspection and proof of 12-inch mortar rifle No. 1 (cast iron, hooped with steel) fabricated at the South Boston foundry, under contracts of Chief of Ordnance, dated September 21, 1883, and June 28, 1884.

Subject of measurement.	DIMENSIONS.		VARIATIONS.		Remarks.
	Prescribed.	Actual.	Allowed.	Actual.	
Length of chamber	18.5	19.25		+.75	Details as to dimensions of hoops and shrinkages will be found on another sheet.
Length of rifled part of bore	92.	92.		0	
Total length of bore	110.5	111.25		+.75	
Thickness of metal at breech	17.	16.2		−.8	
Total length of mortar	127.5	127.45		−.05	
Diameter of bore across lands	12,	11.998	+.003	−.002	
Diameter of chamber	11.85	11.848	+.003	−.002	
Length of vent-bushing	15.875	15.875		0	
Diameter of vent-bushing	0.98	0.98		0	
Pitch of screws on vent-bushing (threads per inch).	8.	8.			
Diameter of vent	.2	.2			
Distance of vent from bottom of chamber.	5.	4.95		−.05	
Distance of vent to left of vertical plane through axis of bore.	3.	.3			
Number of grooves and lands	40	40			
Width of grooves	.6425	.6425			
Depth of grooves	.065	.0595	−.005	−.0055	
Width of lands	.3	.3			
Lands rounded with radius of	.01	.01			
Radius of fillet (bottom of lands.)	.06	.08			
Twist					Increasing from one turn in 100 cals. at the origin to one turn in 35 cals. at 3½ inches from muzzle; then uniform, and one turn in 35 cals. to the muzzle.
Full depth of grooves begins at inches from chamber.	1.75	.75			
Distance of chamber to beginning of rifling,	0.5	0.5			
Exterior diameter of gun at 1 inch from muzzle.	22.54	22.542		.002	
Exterior diameter of gun at shoulder in front of hoops.	32.5	32.52		+.03	
Exterior diameter of gun over hoop A_1	37.1	37.1			
Exterior diameter of gun over hoop B_1	41.	41.			
Exterior diameter of gun over trunnion hoop.	42.4	42.45		+.05	
Exterior diameter of gun over hoops B_2 to B_6.	41.5	41.5+			
Exterior diameter of gun over hoop A_6	35.9403	35.9405		+.0002	
Exterior diameter of gun over breech	31.0386	31.039			
Diameter of trunnions	12.	11.99		−.01	
Length of trunnions	6.	6.			
Length of surface of gun hooped (row A)	65.75				
Diameter of same					Varies for each zone. (See table.)
Length of surface (inner row) hooped (row B).	54.75				
Diameter of same					Varies for each zone. (See table.)
Distance from muzzle to cylinder in front of hoops.	49.5	49.5			
Length of cylinder	4.	4.			
Distance from trunnions to muzzle	75.	74.92		−.08	
Distance from rear hoop to tangent at breech.	8.25	8.25			
Number of hoops, inner row	8	8			
Number of hoops, outer row	6	6			

Marks on "face" of mortar: "12-inch S. B. I. W.,—1884, D. A. L. Wt., 30,330 pounds."
Weight, 30,330 pounds.
Preponderance at tangent to breech, 124.4 pounds—say 125 pounds.

Data relative to shrinkage of hoops.

[12-inch M. L. rifled mortar. Third approximation. Exterior of finished turned bore ".05 small.]

Sections.	Theoretical shrinkages.		Actual shrinkages.		Theoretical compression of bore $\frac{\Delta R}{R}$	Anticipated compression of bore proportional to that in experimental cylinder.	Actual compression of bore.	Pressure in pounds per square inch corresponding to actual compression of bore.
	ϕ_1	ϕ_2	ϕ_1	ϕ_2				
	Thousandths.	*Thousandths.*	*Thousandths.*	*Thousandths.*	*Thousandths.*	*Thousandths.*	*Thousandths.*	*Pounds.*
B_6	1.400	1.225	1.376	1.219	Bottom of chamber.*			
B_5			1.399	1.241				
			1.420	1.258	†1.211	†1.229	†1.351	†24,100
B_4			1.345	1.258	1.216	1.194	1.277	23,000
B_3			1.355	1.266	0	1.210	1.286	23,200
B_2 (trunnions)	1.400	1.425	1.347	1.461	1.201	1.200	1.251	22,500
B_1	1.280	1.110	1.200	1.027	1.19	.995	1.005	19,500
A_1	1.324	0	1.255	0	‡.761	‡.747	.805	15,400
Cylinder in front of hooping	0	0	0	0	0	0	.251	5,400

REMARKS.—An absolute error of ."001 in the star-gauging is equivalent to a relative error of .084 thousandths.

* Owing to contraction of bottom of chamber, due to its form, measurements could not be made.

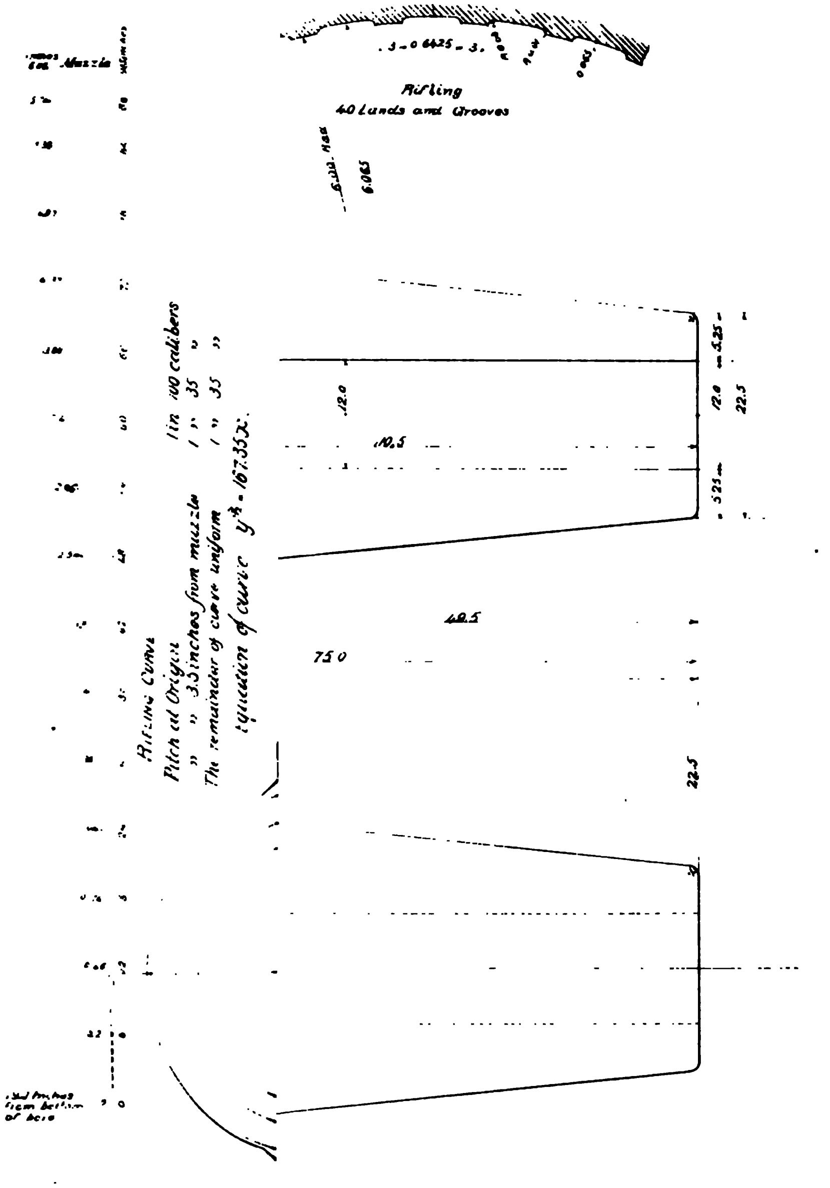
† In chamber.

‡ This does not take into account either the resistance due to the unhooped portion just in front or the aid derived from hoop B just in rear.

CHAS. S. SMITH,
Captain, Ordnance Department.

ORDNANCE OFFICE, *November* 11, 1884.

PLATE I.


Rifling
40 Lands and Grooves
6.065
12.0
10.5
49.5
75.0
22.5
5.25
Rifling Curve
Pitch at Origin 1 in 100 calibers
" " 3.5 inches from muzzle 1 " 35 "
The remainder of curve uniform 1 " 35 "
Equation of curve y² = 167.35x.
Muzzle
Inches from bottom of bore

Chas S. Smith
Captain of Ordnance,
Principal Assistant.

Brig. Gen'l Chief

Appendix 25—1885.

APPENDIX 26.

EXPERIMENTAL CYLINDER FROM THE 12-INCH CAST-IRON RIFLED MORTAR, HOOPED WITH STEEL.

By CAPT. D. A. LYLE AND LIEUT. H. D. BORUP.

COMPOSITION.

The experimental cylinder for the 12-inch cast-iron muzzle-loadin rifled mortar, hooped with steel, was composed of three parts, viz:

(1) The body (cast iron).
(2) The A hoop (Midvale steel).
(3) The B hoop (Midvale steel).

MATERIALS.

(1) *The cast-iron body.*

This was taken from the lower end of the sinking head and near th muzzle of the mortar. An initial tension-ring 3 inches thick was take out between the face of the piece and the body for the experimental cylinder. The end next to the muzzle was marked "face," and is so designated in all references to this end.

(2) *Hoops.*

These were from Midvale open-hearth steel, and were marked as follows: the inner hoop, A*x*; the outer, B*x*. The hoops were received i the rough-finished state.

Dimensions and weights (rough finished).

	Hoop A*x*.	Hoop B*x*.
Exterior diameter ....inches..	36.46	41.7
Interior diameter ....do...	30.74	35.
Length ....do...	7.4	7.
Weight ....pounds..	628	7

TABLE A.—*Test specimens.*

[Taken from initial tension-ring next to the muzzle before hooping.]

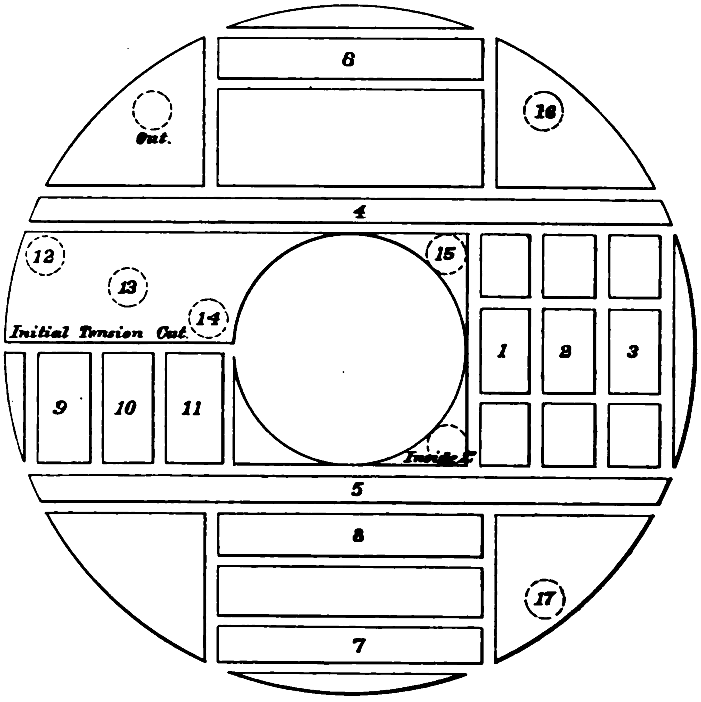
No. of specimen.	Kind.	How taken.	Numbers.	Where tested.
2	Tension	Tangential, inside	Nos. 4 and 5	Watertown Arsenal.
3	Compression	Tangential	No. 6, inside; No. 7, outside; No. 8, inside.	Do.
6	Tenacity	do	Nos. 1 and 11, inside; Nos. 2 and 10, middle; Nos. 3 and 9, outside.	South Boston Iron Works.
8	do	Longitudinal	Nos. 12, 16, 17, and "out," outside; No. 13, middle; Nos. 14, 15, and "inside," inside.	See pages 482, 483, Report Chief of Ordnance, 1884, f tests.

TABLE B.—*Test specimens.*

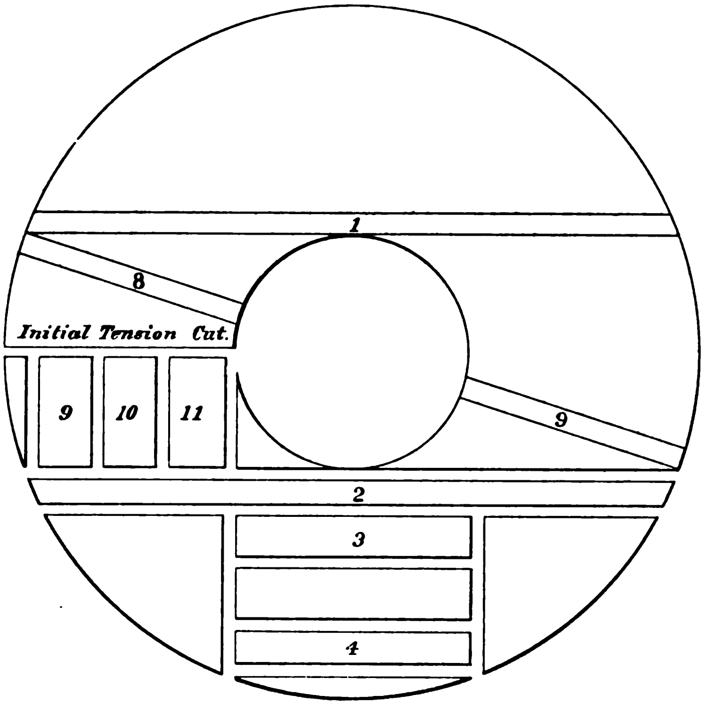
[Taken from initial tension-ring from "face" of experimental cylinder after unhooping. Disk =2.5 inches thick.]

No. of specimen.	Kind.	How taken.	Numbers.	Where tested.
2.......	Tension	Tangentially, inside.	Nos. 1 and 2	Watertown Arsenal.
2.......	Compression..	Tangentially........	No. 3, inside; No. 4, outside.	Do.
2.......	....do	Radially	Nos. 8 and 9, taken from opposite sides.	Do.
3.......	Tenacity......	Tangentially........	No. 9, outside; No. 10, middle; No. 11, inside.	South Boston Iron Works. See page 483, Report of Chief of Ordnance, U.S.A., 1884.

Initial tension-ring taken from the muzzle of 12-*inch M. L. rifled mortar, between the face and the experimental cylinder.*



Initial tension ring (2.5 inches thick) taken from cast-iron body of experimental cylinder from 12-inch M. L. rifled mortar.



AFTER UNHOOPING.

INITIAL TENSION.

[Determined from the two disks noted above. For details see page 483, Report of Chief of Ordnance, 1884.]

	Pounds.
Before hooping	15,750
After unhooping	12,000

Physical properties of the Midvale steel hoops.*

Hoop.	Length of specimen.	Elastic limit per square inch.	Elastic extension.	Tensile strength per square inch.	Elongation after rupture.	Contraction of area.
	Inches.	*Pounds.*	*Inches.*	*Pounds.*	*Per cent.*	*Per cent.*
Ax..	6	63,000	.002033	115,200	13.0	27.6
	6	59,000	.001883	112,600	12.3	27.6
	3	63,000	.002200	112,000	18.3	32.5
	3	60,000	.001867	111,870	15.7	26.4
	6	65,000	.002183	112,080	12.67	24.4
	6	63,000	.002150	110,800	12.67	27.6
	*(?)	60,000	.001990	Compression specimen.		
Bx..	6	68,000	.002033	117,600	8.9	33.6
	6	65,000	.002067	112,000	15.3	39.2
	3	71,000	.002467	116,460	16.0	35.4
	3	64,000	.002000	112,650	16.0	29.3
	6	57,000	.001867	108,440	10.5	33.6
	6	67,000	.002250	114,000	12.8	30.8
	*(?)	55,000	.001770	Compression specimen.		

*The information given in this table was kindly furnished by Lieut. F. E. Hobbs, Ordnance Department, U. S. A.

Computations of elastic strength of experimental cylinder from 12-inch M. L. rifled mortar.

[Data furnished by the Ordnance Office from the physical tests of the metal made before hooping.]

Cast-iron body.	Hoops Midvale steel.
$R_0 = 6''$ $\theta_0 = 5$ tons. $\rho_0 = 9.25$ tons. $e_0 = .0006$ (at E. L.). $E_0 = 8,333$ tons.	$R_1 = 15''.5$ $R_2 = 17''.95$ $R_3 = 20''.75$ $\left.\begin{matrix}\theta_1 = \rho_1 \\ \theta_2 = \rho_2\end{matrix}\right\} = 23.203$ tons. $e_1 = e_2 = .00165$ (at E. L.). $E_1 = E_0 = 14,063$ tons.

Comparison of principal results obtained from computation.

Subject.	Computer.		
	Capt. C. S. Smith.	Lieut. H. D. Borup.	Capt. D. A. Lyle.
P_2	3.689	3.689	3.689
P_1	7.618	7.6174	7.6179
P_0	12.0633	12.0628	12.0633
p_2	$0.4245 \times p_1$	$0.4245 \times p_1$	$0.42457 \times p_1$
p_1	(−) 1.3123	(−) 1.3308	(−) 1.3303−
$P_1 + p_1$	6.306	6.2866	6.2876+
$(P_1 + p_1)$	4.251	4.2508	4.2508−
Diff.	2.055	2.0358	2.0368+
$\frac{{}^{*}d\,\Delta R_0}{R_0}$	.0008745	.0008874	.0008876
$\frac{{}^{*}\Delta R_0}{R_0}$	(−) .0014575	(−) .0014791	(−) .0014792
$\frac{{}^{\dagger}\Delta R_0}{R_0}$	.000553	.000563	.000563+
ϕ_1	.001795	.001789	.001798
ϕ_2	.001581	.0015718	.0015795+
S_1	.055658	.055459	.005736
S_2	.056754	.0564276	.056705+

Adjusted for allowed variation.

ϕ_1	.00168	.00168	.001685
ϕ_2	.00168	.00167	.001677
S_1	.0522	.0520	.05224
S_2	.0603	.0599	.06020+

* System at rest. † System in action.

INSTRUCTIONS.

The following instructions were received from the Ordnance Office, U. S. A., in regard to the hooping experiments, viz:

ORDNANCE OFFICE, WAR DEPARTMENT,
Washington, D. C., May 6, 1884.

SIR: By direction of the Chief of Ordnance I have to request that you will please cause the work of hooping the experimental cylinder taken from the 12-inch mortar casting to be proceeded with so soon as the hoops are received from the Midvale Steel Works, using for this purpose the two hoops marked A*x* and B*x*, respectively.

Instructions are herewith inclosed, giving the prescribed shrinkages for this experimental hooping and showing how the work is to be executed.

Great care will be required, both in the supervision and execution of this work, or the shrinkages actually obtained will be greater or less than the prescribed beyond the allowed variation.

A preliminary report will be made as early as practicable, giving the mean diameters, the shrinkages actually obtained; the successive compressions of the casting with the hoops in place and the extension of the hoops, and the restoration and permanent set of the casting and of the hoops after the successive removal of the hoops.

A further and more complete report may be submitted subsequently, showing in tabular form the absolute measurements, with the linear and proportional differences, and a recapitulation of the general effects produced on the casting and on the hoops with the hoops in place and after their removal, so far as that may be done. (See in this connection Notes on the Construction of Ordnance, Nos. 14 and 26.)

Respectfully, your ob't serv't,

CHARLES S. SMITH,
Captain of Ordnance, Principal Assistant.

Capt. D. A. LYLE,
Ordnance Dept., U. S. A., Boston, Mass.

General instructions for hooping and unhooping experimental cylinder for 12-inch muzzle-loading mortar.

(1) The interior diameter of the first or inner hoop to be turned to a mean diameter of 31 inches, with an "allowed variation" of —0.0035 inch; the interior diameter of the second or outer hoop to be turned to a mean diameter of 35.5 inches, with an "allowed variation" of —.0035 inch; the lengths of the two hoops to be the same, and as near 7.25 inches as possible. As regards the parallelism of the ends, eccentricity, and conicalness of the interior surfaces, the "allowed variations" to be as follows: For parallelism, 0.0035 inch; for eccentricity, 0.005 inch; for conicalness, 0.0035 inch.*

(2) The casting to be bored to as near 12 inches as possible, and not exceeding 12.05 inches; the ends to be squared up, giving a right cylinder with parallel bases 7.75 inches in length. The exterior to be turned to a mean diameter equal to the mean interior diameter of the first hoop plus a shrinkage of † .00168 inch per inch of that diameter, with an "allowed variation" between the prescribed diameters of the surfaces of contact of +0.0035 inch and —0.000 inch.

(3) After the first hoop has been put in place on the casting and has cooled, the exterior to be turned to a diameter equal to the interior diameter of the second hoop plus a shrinkage of ‡ .00168 inch per inch of that diameter, with an "allowed variation" of —0.0035 inch and +0.000 inch. The exterior of this hoop may be turned to the finished diameter of 41.5 inch before the hooping, which is not admissible, however, in the actual hooping of guns. The "allowed variation" for this diameter to be 0.02 inch.

(4) As soon as practicable after the required measurements have been taken, the hoops to be successively expanded by heat, and the casting withdrawn, after the mode described in "Notes on Construction of Ordnance," No. 14, page 3.

The hoops to be removed from the bath of molten metal as speedily as possible after the withdrawal of the casting, to prevent their being injured, as far as possible

MODE OF EXECUTING HOOPING.

The casting prepared for hooping is to be placed vertically on skids, the bore closed at bottom with a wooden disk made water-tight with clay around the inside of the cylinder and having a ¼-inch hole in the center for the exit of the cold water, with which the bore is to be kept filled by a hose during the operation. The hoops may be heated for application by a wood fire surrounded by a flask of iron, preferably a perforated sheet-iron cylinder open at the ends, which will take up little heat and allow a close approach to the fire. Care should be taken to have the hoops heated uniformly, and to avoid raising the heat too high. A temperature of about 600° F. will suffice, and the expansion of the hoop should be kept within about twice the prescribed shrinkage, say from $\frac{2.5}{1000}$ to $\frac{3.5}{1000}$ of the interior diameter. The hoop after being taken from the fire is to be brushed clean and lowered upon the casting until it rests upon supports that shall maintain it centrally on the casting, or at equal distances from the two ends. The transfer from the fire to the casting should be effected without unnecessary delay, as the hoop will cool and contract rapidly. As soon as the hoop has cooled down, so as to set on the casting, water should be sprinkled on it, using a watering-pot with a finely perforated sprinkler—sparingly at first, but by degrees more plentifully, and taking care, by moving around the hoop, to cool it uniformly. After twenty-four hours (or as soon as practicable thereafter) the required measurements will be made.

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* See Notes on the Construction of Ordnance, No. 5 and No. 26, pp. 17 and 19.

† Total shrinkage about .052 inch +.0035 inch.

‡ Total shrinkage about .060 inch —.0035 inch.

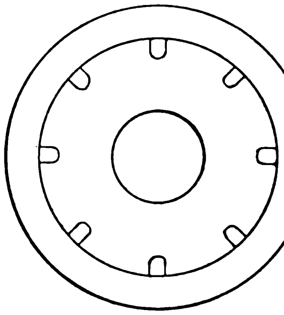
PRESCRIBED MEASUREMENTS.

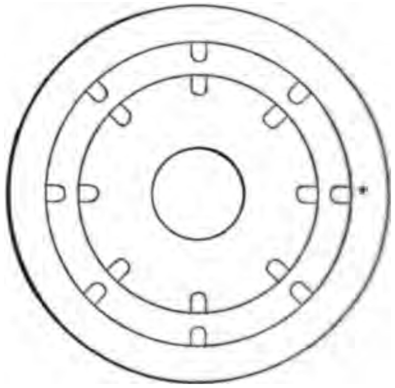
(1) Interior diameters of the hoops prepared for hooping and exterior diameters of outer hoop.
(2) Interior and exterior diameters of the casting prepared for hooping.
(3) Interior diameter of casting after application of first hoop.
(4) Interior diameter of first hoop after application.
(5) Exterior diameter of first hoop prepared for second hoop.
(6) Interior diameter of casting after application of second hoop.
(7) Interior diameter of first hoop after application of second hoop.
(8) Interior diameter of second hoop after application. (All measurements to be made when the hoops are cold.)
(9) Interior diameter of casting after removal of second hoop.
(10) Interior and exterior diameters of first hooping after removal of second hoop.
(11) Interior and exterior diameters of second hooping after removal.
(12) Interior and exterior diameters of casting after removal of first hoop.
(13) Interior and exterior diameters of first hoop after removal.

MODE OF EXECUTING MEASUREMENTS.

(1) *Prepared for hooping.*—Each face of cylinders and hoops to be scored with 4 diameters, which will be marked with numbers. Coincident with these scores 4 diameters, both exterior and interior, to be measured at 0.1 inch distance within each face* and at such additional points between the faces as may be deemed necessary for ascertaining the mean diameter and verifying the workmanship. All measurements to be made in the planes determined by the scores. (See Notes on the Construction of Ordnance, No. 5.)

(2) *After hoops are in place.*—Interior diameter of bore and exterior diameters of hoops to be measured as before, the 4 diameters scored on each face of hoop being opposite to the correspondingly numbered ones on cylinder. For measuring the interior diameters of hoops, short shallow grooves are made on each face of cylinder, and subsequently on inner hoop, as shown on following sketch, and of just sufficient size to expose the extremities of the diameters before measured at 0.1 inch within the faces, and to allow sufficient room for manipulating the points of the vernier calipers. For this purpose the dimensions of the groove to be about ⅜ inch wide and about 0.2 inch deep from the face of the hoop.


ONE HOOP.


TWO HOOPS.

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*Inasmuch as these diameters must subsequently be measured with vernier beam calipers (*i. e.*, whilst the hoops are in place on the cylinder), it would be well to measure them at this time also with this instrument, in addition to the measurements with "points." In using the beam calipers it will be, of course, highly important that the inner edge of the hoop should not be the least burred, so that these edges must, in the first place, be carefully finished and great care taken throughout the operations not to bruise them.

The grooves are made by drilling holes near the outer face of cylinder and finishing the grooves at these portions with a hand chisel.

The film of metal between drill-holes and inner surface of hoop is left to be taket out last, the job being given to a careful workman, with ins care not to injure inner surface or edge of hoop.*

(3) *After hoops are removed.*—The same measurements to be repeated as before, except that for the cylinder and the interior hoop the exterior diameter will be measured at points just beyond the grooves, and for exactness measurements should have been made at these same points before the assemblage.

HOOPING OPERATIONS UPON THE EXPERIMENTAL CYLINDER FOR 12-INCH M. L. R. MORTAR.

The operation of shrinking on the hoops was conducted in the open air, in the vicinity of a crane, by means of which the hoop could be lifted from the fire, shifted over the cylinder, and lowered. The cylinder and hoop were placed in the circumference of a circle whose center was the vertical axis of the crane and whose radius the length of its arm.

The hoop, mounted on four iron supports and leveled, was surrounded by a perforated sheet-iron flask, of sufficient diameter to leave about one foot between it and the exterior of the hoop. The lower edge of the hoop was about 6 inches from the ground, on which were placed fine shavings to the depth of an inch, together with a few small pieces of pine.

The cylinder, also leveled, rested on an iron surface similar to the bed-plate of a planer, and on this plate, at the extremities of four diameters outside of and close to the cylinder, were placed four rectangular pieces of iron, accurately planed so as to be one-fourth inch in height.

At the bottom of the bore of the cylinder was placed a wooden disk fitting water-tight and having a hole one-fourth inch in diameter in its center. Connections were made with two neighboring hydrants by two pieces of one-inch hose. One hose terminated in a piece of gas-pipe with one end curved, the circular part being of a little greater diameter than the hoop.

Its inner surface was pierced with holes to give vent to the jets of water for cooling the exterior of the hoop. The other hose was used to keep the bore filled with water. Four chains, with long links, terminated at one end in a ring common to all and attached to the crane, and at the other in an iron bar 1 inch wide and bent at right angles at its lower extremity to form a kind of hook, to engage the hoop in lifting it from the fire.

For regulating the expansion of the hoops two wooden rods terminating in iron points were used. This expansion was to be kept within $\frac{2.5}{1000}$ and $\frac{3.5}{1000}$ of the diameter.

The lengths of the rods were:

	Maximum.	Minimum.
	Inches.	*Inches.*
For inner hoop (Hoop A)	31.10458	31.07359
For outer hoop (Hoop B)	36.0216	35.9857

In the manipulation of the first hoop the hooks were not placed under the hoop until after the minimum wire had entered, and as the fire was very fierce some time was occupied in placing them, which allowed the hoop to expand a little in excess of that allowed.

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*This work may be begun for the successive interior measurements of each hoop as soon after the shrinkage as the hoop and cylinder may have become cool enough to work with.

In putting on the second hoop the hooks were placed in position before the fire was lighted, so that no unnecessary delay occurred.

The shavings being lighted, pine wood was laid with one end resting on the ground and the other against the hoop, both inside and out. As soon as the minimum wire entered, the hoop was raised, brushed clean on the inside, and lowered over the cylinder until it rested on the small pieces of iron previously mentioned.

The bore in the mean time had been filled with water, and as soon as the hoop was lowered the plug in the bottom was removed and the water from the hose turned in the bore.

When the hoop had closed the other pipe was brought around the hoop and water turned on slowly at first, but more plentifully afterwards. The water was applied first near the base and afterwards raised slowly to the top. Care was taken to bring the corresponding diameters together.

Details of heating.

	Inner hoop (Hoop A).	Outer hoop (Hoop B).
Date	July 2, 1884.	July 18, 1884.
	a. m.	p. m.
Fire lighted	$1^h\ 12^m$	$10^h\ 16^m$
Minimum wire entered	1 28	10 42
Hoop removed from fire	1 38	10 43
Hoop in position	1 40	10 45
Water turned on in bore	1 41	10 46
Hoop closed	1 58	11 00
Water turned on outside	1 58	11 01
Water in bore shut off	2 31	11 44
Water on exterior shut off	2 31	11 48

RÉSUMÉ.

Time of heating	[*]26^m	[†]27^m
Time required to clean hoop and get it in position	2^m	$1\frac{1}{2}^m$
Time of cooling	39^m	44^m
Time from application of hoop until it closed on cylinder.	18^m	15^m
Total duration of experiment	$1^h\ 48^m$	$1^h\ 39^m$
Temperature of water at hydrant	72°	65°
Maximum temperature of water in bore	93°	81°.5
Maximum rise of temperature of water in bore	21°	16°.5

[*] This hoop was ready for application in 16 minutes, but its removal was delayed for the reason given above.

[†] The fire for the first hoop was more intense than that used for the second, experience having shown that but comparatively little heat was necessary to obtain the required expansion.

ADDITIONAL NOTES.

Inner hoop (Hoop A).

This hoop was not placed exactly concentric with the cylinder, one side coming in contact before the other.

The maximum openings between the two being at $1^h\ 47^m$ p.m.=.025″; $1^h\ 52^m\ 30^s$ p.m.=.02″; $1^h\ 58^m$=0.

At 2.03 p. m. (23 minutes after application) the heat had reached a point about two-thirds the thickness of the cylinder, estimated from the exterior.

At 2.04 the heat had penetrated throughout the casting. The inward progress of the heat was roughly followed by the hand.

At 2.17 the inner half of the cylinder was hotter than the outer.

At 2.19 hoop cool enough to "bear the hand" on the exterior; heat barely perceptible on the interior.

At 2.31 the cast-iron cylinder and steel hoop were sufficiently cool to shut off the water; a plug was placed in the hole in the wooden disk to keep the bore full.

Outer hoop (Hoop B).

This hoop was placed with one point of a scored diameter in contact with the corresponding point on the cylinder. The maximum openings between the hoops were as follows:

Time a. m.	Maximum opening.
$10^h\ 45^m$	Hoop in position.
$10^h\ 45^m$	=.07″.
$10^h\ 49^m$	=.035″.
$10^h\ 53^m$	=.03″.
$10^h\ 54^m$	=.02″.
$10^h\ 57^m$	=.015″.
$10^h\ 57^m\ 30^s$	=.01″.
$11^h\ 00^m$	=0.0″. Hoop clamped.
$10^h\ 50^m$	Heat had penetrated inner hoop.

N. B.—The maximum openings for both hoops are only approximate, as the observers did not have the proper gauges to make accurate observations.

Experimental cylinder from 12-inch M. L. R. mortar.

TEMPERATURE OF WATER IN BORE.

Object: Application of inner hoop (Hoop A). *Date:* July 2, 1884. *Hydrant temperature:* 72° Fahrenheit. *Water rate:* Not measured. *Temperature of air:* 77° Fahrenheit.]

	Time.	Temperature.
	h. m.	°
Hoop in position on cylinder at	1 40	....
Hydrant temperature at	1 50	72
Temperature of water in bore:		
Temperature = hydrant temperature at	1 50	....
Temperature at	2 09	91
Temperature at	2 13	93
Temperature at	2 17	91.5
Temperature at	2 21	91.5
Temperature at	2 25	90.5
Temperature at	2 29	86
Temperature at	2 31	86
Water shut off at	2 31	....
Temperature at	2 45	91
Temperature at	2 48	91.5
Temperature at	2 52	91
Temperature at	2 58	91
Water let out of bore at	3 00	....

[*Object:* Application of outer hoop (Hoop B). *Date:* July 18, 1884. *Hydrant temperature:* 65° Fahrenheit. *Water:* Rate not measured.]

	Time.	Temperature.
	h. m.	°
Hoop in position on cylinder at.....	10 45	....
Hydrant temperature at	10 45	65
Temperature of water in bore at ...	11 20	80
Temperature of water in bore at...	11 26	79.5
Temperature of water in bore at...	11 33	78.5
Temperature of water in bore at...	11 39	74
Temperature of water in bore at ...	11 44	72.5
Water in bore shut off at...........	11 44	....
Temperature of water in bore at...	11 46	75
Temperature of water in bore at ...	11 50	80
Temperature of water in bore at ...	11 53	81
Temperature of water in bore at...	11 54	81.5
Temperature of water in bore at ...	11 55	81.5
Water let out of bore at	11 55	....

UNHOOPING EXPERIMENTAL CYLINDER CUT FROM 12-INCH M. L. R. MORTAR.

I.—*Removal of second or outer hoop* (*July* 26, 1884).

PREPARATIONS FOR UNHOOPING.

A circular iron plate with a central opening was placed horizontally upon three conical legs or supports, so as to elevate it about 18 inches from the foundry floor; the experimental cylinder carrying the two steel hoops was placed upon this plate concentric with the central opening. The size of the hole was such as to permit, without difficulty, the passage of the cylinder and inner hoop, but not the outer hoop. Exterior to this cylinder, and resting on edge upon the same plate, was a flask of boiler iron three-eighths inch thick, whose diameter was about 6 inches greater than that of the cylinder with its two hoops. The height of this flask was about the same as the length of the cylinder. It was made in two sections (each a semi-circle), and held together by bolts and keys, easily removable. The assembled flask was placed concentrically about the cylinder. The annular space between the flask and cylinder was filled in with molding-sand, leaving a narrow annulus next to outer hoop (about 1.5 inches thick, measured radially) for the introduction of molten iron, which was to furnish the heat for expanding the outer hoop. This open space was preserved by the employment of an annulo-segmental pattern of wood, whose curvilinear boundaries were arcs of concentric circles, the inner one having the same curvature as the exterior surface of the outer hoop.

This pattern was moved along around the exterior of the hoop, and the sand filled in until the mold was completed. In order to remove readily the iron used for heating as soon as it had expanded the hoop sufficiently, three wooden partitions 1 inch thick were placed about 120° apart, so as to divide the empty space left for the melted iron into three equal parts. Over the middle points of each of these cavities was placed a cup-shaped runner, lined with molding-sand, and provided with a rectangular slot in the bottom about 2 inches long and 0.5 inch wide, to permit the passage of the melted iron into the annular segments next to the hoop. These cup-like cavities caught the metal flowing from the ladle, and prevented the stream from striking the hoop in pouring, and thus overheating one spot unnecessarily.

A few inches of molding-sand was placed beneath the cylinder, upon which it could fall without injuring the edges when the outer hoop was expanded.

UNHOOPING.

When all was ready, six men with three small ladles simultaneously poured molten iron in until the space around the outer hoop was filled. As soon as this hoop expanded it released the cylinder and inner hoop, which fell upon the sand beneath, due to its own weight, without being affected by the heat at all. So instantaneous was its fall that the exterior surface of the inner hoop was cold when examined a few seconds after the fall. The instant the cylinder and inner hoop were released, the outer flask was torn away by loosening the keys and bolts, the molding-sand removed, and the iron, which had chilled, removed from contact with the hoop. This latter was easily done on account of the segments into which it was divided by the three wooden partitions. The contraction due to cooling was not great enough to cause the iron to cling to the exterior of the hoop.

The heat from the molten iron produced in four minutes a higher temperature in the outer hoop than that used in expanding it before shrinking on. The color of the steel ran up between brown and blue, with a tendency towards the blue. The hoop was allowed to cool in the air, when both it and the cylinder were measured.

Time of unhooping.

Melted iron poured in at	$3^{h}\ 30^{m}$ p. m.
Cylinder dropped out at	$3^{h}\ 32^{m}\ 30^{s}$ p. m.
Time required to expand outer hoop	$2^{m}\ 30^{s}$ p. m.
Iron (chilled) removed from contact with outer hoop	$3^{h}\ 34^{m}$ p. m.
Time from removal of cylinder to removal of heated iron	$1^{m}\ 30^{s}$
Time hot iron in contact with outer hoop	4^{m}

II.—*Removal of first or inner hoop* (*July* 29, 1884).

The arrangements for removing this hoop were similar to those for the outer hoop, except that but two wood partitions were used for dividing the iron into segments, instead of three, which probably accounted partially for the difficulty encountered later. Two runners, instead of three, were also employed, and the molten iron struck the hoop in pouring, which should have been avoided. The iron was too hot when poured, and in attempting its removal a piece about 4 inches square adhered to the hoop at or near one pouring-point, and a piece about 12 inches long and of the whole width of the hoop adhered to the latter at the other pouring point. These pieces resisted all attempts at their removal, and were allowed to remain until cold.

Time of unhooping.

Melted iron poured at	$4^{h}\ 7^{m}$ p. m.
Cast-iron cylinder dropped out at	$4^{h}\ 8^{m}\ 40^{s}$ p. m.
Time required to expand inner hoop	$1^{m}\ 40^{s}$
Flask removed at	$4^{h}\ 9^{m}$ p. m.
Greater part of chilled iron off at	$4^{h}\ 10^{m}$ p. m.
Time hot iron in contact with hoop	3^{m}

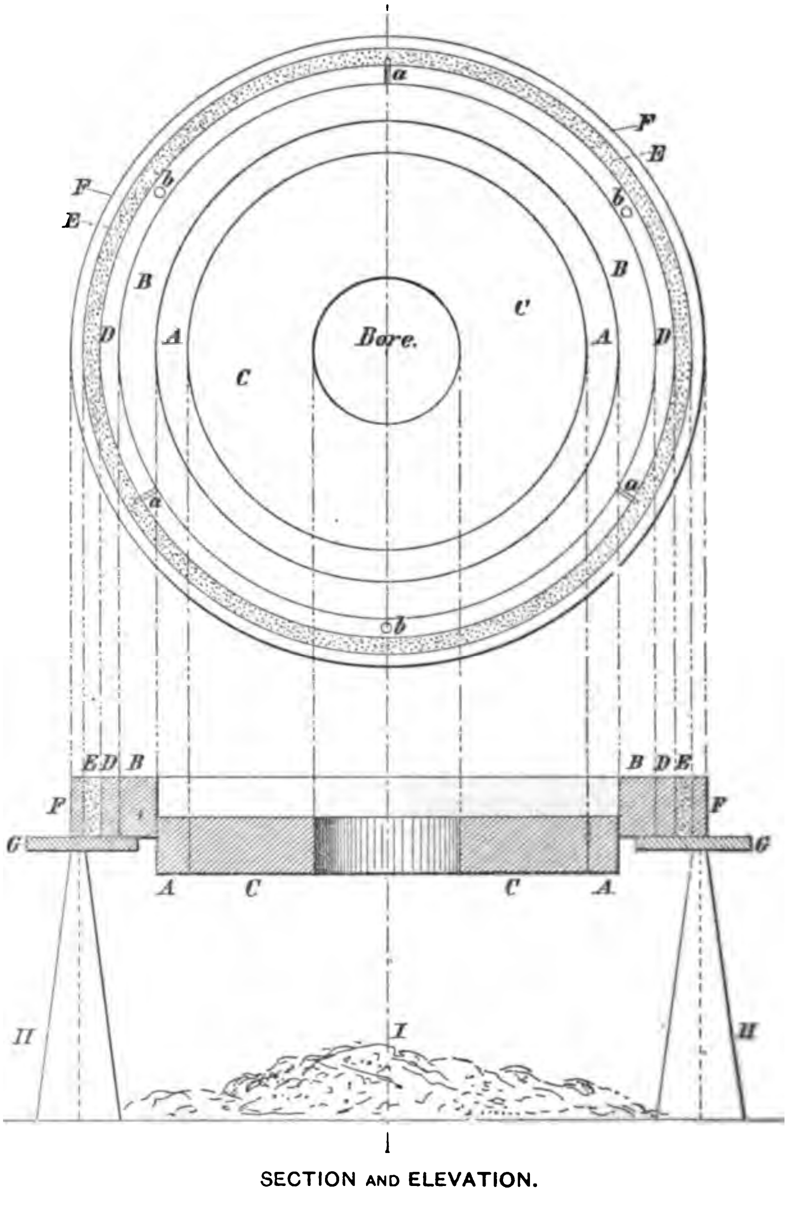
Part of iron which adhered to hoop was left until cool. Hoop overheated in two segments by long contact with hot metal.

REMARKS.

The results of the experiments are tabulated for reference, and are given in Tables A to F, both inclusive. The detailed measurements are

DIAGRAM SHOWING METHOD OF UNHOOPING.

PLAN.



SECTION AND ELEVATION.

EXPLANATION OF DIAGRAM.—C C, cast-iron body; A A, inner hoop (Hoop A); B B, outer hoop (Hoo B); D D, molten cast-iron; E E, molding-sand; F F, boiler-iron flask; G G, circular cast-iron plate H H, conical supports; I, molding-sand to prevent injury to cylinder in falling; *a a a*, wooden partitions to divide the poured metal into segments for easy removal; *b b b*, pouring-holes.

NOTE.—In the section and elevation the cylinder with A hoop is shown in the act of dropping out o Hoop B.

contained in Tables 1 to 37, both inclusive, which form the appendix to this report.

The measurements made upon the hoops after removal, by means of molten iron, are practically valueless, on account of the distortion due to the great heat and to the clinging of the iron to the metal of Hoop A*x*.

TABLE A.—*Experimental cylinder 12-inch M. L. R. mortar.*

PRESCRIBED AND ACTUAL DIMENSIONS BEFORE APPLICATION, ETC.

[EXPLANATION OF TERMS USED IN TABLES.—(1) *Eccentricity* is the difference between the greatest and least diameter in any set of four diameters. (2) *Mean eccentricity* is the difference between the greatest and least means of the measurements taken on the four series of diameters. (3) *Conicalness* is the difference between the mean diameters, determined from measurements at 0.1″ from each end made with vernier beam-callipers. (4) *Maximum constriction* is the difference between greatest and least means of the sets of four diameters. (5) *Parallelism* is the difference between the exterior and interior lengths, measured at either end of any scored diameter. (6) *Mean parallelism* is the difference between the exterior and interior mean lengths.]

Subject.	Casting.			
	Dimensions.		Variations.	
	Prescribed.	Actual.	Allowed.	Actual.
	″	″	″	″
Interior diameter	12.0	12.0286	+ .05 − .00	+.0286
Exterior diameter:				
Theoretical	31.05208			
Maximum	31.05558	31.0482	+ .0035	
Minimum	31.05208		− .0000	−.0039
Length	7.75	7.7564		+.0064
Relative shrinkage (per 1 inch)	.00168			
Absolute shrinkage:				
Theoretical	.05208			
Maximum	.05558		+0.0035	
Minimum	.05208	.0514	−0.0000	−.00068
Parallelism			.0035	.004
Eccentricity			.005	*.0008
Conicalness			.0035	*.0015 †.0001

Subject.	Inner hoop (Hoop A*x*).			
	Dimensions.		Variations.	
	Prescribed.	Actual.	Allowed.	Actual.
	″	″	″	″
Interior diameter	31.0	‡30.9968 §[30.9961]	−.0035 +.000	‡−.0032 §−.0039
Exterior diameter:				
Theoretical	35.95964			
Maximum	35.95964	35.9523	+.000	
Minimum	35.9561		−.0035	−.0073
Length	7.25	7.2490		−.0010
Relative shrinkage (per 1 inch)	.00168			
Absolute shrinkage:				
Theoretical	.05964			
Maximum	.05964		+0.000	
Minimum	.0561	.0560	−0.0035	−.00364
Parallelism			.0035	0.0
Eccentricity			−.005	*.00038
Conicalness			.0035	*0.001 †.0026

TABLE A.—*Experimental cylinder 12-inch M. L. R. mortar*—Continued.

Subject.	Outer hoop (Hoop Bx).			
	Dimensions.		Variations.	
	Prescribed.	Actual.	Allowed.	Actual.
	"	"	"	"
Interior diameter	35.9	‡35.8963 §35.8960	—.0035 +.000	‡—.0037 §—.0040
Exterior diameter:				
Theoretical				
Maximum	41.5	41.5032	‡.02	+.0032
Minimum				
Length	7.25	7.2475		—.0025
Relative shrinkage (per 1 inch)				
Absolute shrinkage:				
Theoretical				
Maximum				
Minimum				
Parallelism			.0035	.0009
Eccentricity			.005	*.00044
Conicalness			.0035	*.0012 †.0022

* Interior diameter.
† Exterior diameter.
‡ Determined from measurements made 1 inch from each end by vernier calipers.
§ Determined from measurements throughout hoop taken with adjustable rods.

TABLE B.—*Conicalness.*

[The conicalness on interior is determined from measurements made with adjustable rods; on the exterior from measurements made with the diameter calipers, except in cases noted.]

	Cast-iron body.		Inner hoop (Ax).		Outer hoop (Bx).	
	Interior.	Exterior.	Interior.	Exterior.	Interior.	Exterior.
	"	"	"	"	"	"
Before application	.0015	.0001	.001 *.0005	.0026	.0012 *.001	.0022
After application of A hoop	.0022		.0006			
After application of B hoop	.0021		.0015		.0025	.0046
After removal of B hoop	.002		.0003	.0035	.0184 .0198	.0168
After removal of A hoop	.0026	.0002	.0037 *.0022	.0053		

* This measure for the conicalness was determined from measurement made with vernier calipers at the same points as those taken with adjustable points; *i. e.*, at 0".1 from each end.

TABLE C.—*Mean eccentricity.*

	Cast-iron body.		Hoop Ax.		Hoop Bx.	
	Interior.	Exterior.	Interior.	Exterior.	Interior.	Exterior.
	"	"	"	"	"	"
Before application	.0008	.00047	.00038 *.0005	.00028	.00044 *.0005	.00127
After application of A hoop	.0005		*.0013			
After application of B hoop	.00045		*.00075		*.001	.00125
After removal of B hoop	.00026		*.0005	.00076	.01604 *.0165	.01[illegible]
After removal of A hoop	.00105	.00021	.01947 *.0195	.01685		

* Measured by vernier calipers.

TABLE D.—*Mean parallelism.*

	Cast-iron body.	Hoop A*x*.	Hoop B*x*.
•	"	"	"
Before application	.004	0.0	.0009
After removal of Hoop B*x*	....	....	.006
After removal of Hoop A*x*	.005	.0067	....

TABLE E.—*Diameters of bore of experimental cylinder for* 12-*inch M. L. R. mortar before hooping; after application of Hoops* Ax *and* Bx; *also the compressions of the bore due to the application of Hoop* Ax, *Hoop* Bx, *and both hoops.*

Distance from marked face.	Mean diameters of bore ready for hooping, &c.					Compression of bore due to—		
	Before hooping. (*a*)	After application Hoop A*x*. (*b*)	After finishing exterior Hoop A*x*.* (*c*)	After application Hoop B*x*. (*d*)	After finishing exterior Hoop B*x*.† (*e*)	Application of Hoop A*x*. (*a*—*b*)	Application of Hoop B*x*. (*b*—*d*)	Application of both Hoops (total). (*a*—*d*)
	Hor.	Hor.	Hor.	Hor.	Hor.	Hor.	Hor.	Hor.
	Inches.	*Inches.*	*Inches.*	*Inches.*	*Inches.*	*Inches.*	*Inches.*	*Inches.*
0.1 inch	12.0296	12.0201	....	12.0121	....	.0095	.0080	.0175
0.35 inch	12.0296	12.0199	....	12.0119	....	.0097	.0080	.0177
1.375 inches	12.0293	12.0191	....	12.0110	....	.0102	.0081	.0183
2.375 inches	12.0288	10.0191	....	12.0113	....	.0097	.0078	.0175
3.375 inches	12.0285	12.0185	....	12.0104	....	.0100	.0081	.0181
4.375 inches	12.0283	12.0181	....	12.0104	....	.0102	.0077	.0179
5.375 inches	12.0275	12.0179	....	12.0101	....	.0096	.0078	.0174
6.375 inches	12.0285	12.0178	....	12.0100	....	.0107	.0078	.0185
7.15 inches	12.0281	12.0175	....	12.0100	....	.0106	.0075	.0181
7.65 inches	12.0281	12.0179	....	12.0100	....	.0102	.0079	.0181
Grand means	12.0286	12.0186	....	12.0107	....	.0100	.0079	.0079

* Not taken.

† Hoop B*x* finished before application.

TABLE F.—*Summary of results obtained in hooping experiments for 12-inch muzzle-loading rifled mortar.*

Stages when measured.	Mean diameter.						Mean length.		
	Cast-iron body.		A hoop.		B hoop.		Cast-iron body, interior.	A hoop, exterior.	B hoop, exterior.
	Interior.	Exterior.	Interior.	Exterior.	Interior.	Exterior.			
	Inches.	*Inches.*	*Inches.*	*Inches.*	*Inches.*	*Inches.*	*Inches.*	*Inches.*	*Inches.*
Prepared for application of A hoop (*a*)	12. 0286	31. 0482	*30. 9968 (1)				7. 7564	7. 2490	
With A hoop applied (*b*)	12. 0186	31. 0398 (5)	*31. 0398				7. 7575	7. 2449	
Prepared for application of B hoop (*f*)				35. 9523	*35. 8963 (3)	41. 5032			7. 2475
With A and B hoops applied (*c*)	12. 0107	31. 0331 + (5)	*31. 0331 +	35. 9450 (5)	*35. 9450	41. 5492	7. 7580		7. 2466
After removal of B hoop (*d*)	12. 0184	31. 0403 (5)	*31. 0403	35. 9500	*35. 8874 (4)	41. 4945 +	1. 7568	7. 2449	7. 2443
After removal of A hoop (*e*)	12. 0257	31. 0461	*30. 8679 (2)	35. 9032			7. 7553	7. 2441 +	

Linear and proportional differences.	Cast-iron body, Interior: Inches.	Cast-iron body, Interior: Thousandths per linear inch.	Cast-iron body, Exterior: Inches.	Cast-iron body, Exterior: Thousandths per linear inch.	A hoop, Interior: Inches.	A hoop, Interior: Thousandths per linear inch.	A hoop, Exterior: Inches.	A hoop, Exterior: Thousandths per linear inch.	B hoop, Interior: Inches.	B hoop, Interior: Thousandths per linear inch.	B hoop, Exterior: Inches.	B hoop, Exterior: Thousandths per linear inch.
Theoretical shrinkages			. 05208	1. 68			. 05964	1. 68				
Prescribed shrinkages:												
Maximum			. 05558	1. 791+			. 05964	1. 68				
Minimum			. 05208	1. 68			. 05610	1. 562+				
Actual shrinkages			. 0514	1. 658+			. 0560	1. 56				
Compression of cast-iron body by A hoop (*a*—*b*)	. 0100	0. 831+	. 0084	0. 270+								
Elongation of A hoop after application (*b*—*a*)					. 0430	1. 387+						
Compression of cast-iron body and A hoop by B hoop (*b*—*c*)	. 0079	0. 657+	. 0067	0. 215+	. 0067	0. 215	(*f*—*c*.) . 0073	0. 203+				
Elongation of B hoop after application (*c*—*f*)									. 0487	1. 356+	. 0460	1. 108+
Total compression of cast-iron body by A and B hoops (*a*—*c*)	. 0179	1. 488+										
Restoration of cast-iron body and A hoop after removal of B hoop (*d*—*c*)	. 0077	0. 641+	. 0072	0. 232+	. 0072	0. 232+	. 0050	0. 139+				
Restoration of cast-iron body after removal of A hoop (*e*—*d*)	. 0073	0. 607+	. 0058	0. 186+								

Restoration of cast-iron body after removal of both hoops ($e-c$)	0.0150	1.248+	.0130	0.418	....	....	....	....	....	....	....	....	....
Permanent compression ($a-e$)	.0029	0.341+	.0021	0.067+	‡ [.1280]	4.158+	($f-e$) [.0491]	1.365+	($f-e$) .0089	0.247+	($f-d$) .0087	0.209+	

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* From measurements at 0''.1 from ends of hoop, made with vernier beam-calipers.

‡ The grand mean of all diameters after unhooking was 30.9869 instead of 30.8679, as determined from diameters at 0''.1 from each end. Taking the former, we have $a-e$ = 0''.0099 instead of 0''.1289, and relative compression = 0.319+ instead of 4.158 thousandths.

(1). Grand mean of all diameters taken throughout by adjustable rod = 30''.9961

(2) Grand mean of all diameters taken throughout by adjustable rod = 30''.9869.

(3) Grand mean of all diameters taken throughout by adjustable rod = 35''.8960.

(4) Grand mean of all diameters taken throughout by adjustable rod = 35''.8841.

(5) These diameters not measured. They are identical with the interior diameter of their enveloping surfaces.

APPENDIX 27.

REPORT OF EXPERIMENTS CONDUCTED AT THE WEST POINT FOUNDRY IN ASSEMBLING AND DISMANTLING A COMPOUND CYLINDER, REPRESENTING A SECTION OVER THE POWDER CHAMBER OF THE EXPERIMENTAL STEEL 8-INCH BREECH-LOADING RIFLE, DOUBLE-HOOPED.

By LIEUT. ROGERS BIRNIE, JR., ORDNANCE DEPARTMENT, U. S. ARMY.

(4 plates.)

OFFICE OF INSPECTOR OF ORDNANCE, U. S. A.,
WEST POINT FOUNDRY,
Cold Spring, N. Y., April 8, 1885.

GENERAL: I have the honor to transmit herewith a report of the hooping test of a compound cylinder, representing a section over the powder-chamber of the experimental 8-inch steel breech-loading rifle now in course of construction at this foundry. The test was conducted in the manner directed by your instructions dated December 1, 1884, which are appended as part of the report. The assemblage of the section was completed during the month of December, 1884, after which it was allowed to stand about two weeks before being dismantled. A synopsis of the tests of detached specimens of the metal of the elementary cylinders, made upon the United States testing machine, Watertown arsenal, Massachusetts, in connection with the hooping test, is embodied in the report.

Very respectfully, your obedient servant,

R. BIRNIE, JR.,
Lieutenant of Ordnance.

The CHIEF OF ORDNANCE, U. S. A.,
Washington, D. C.

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This work was prosecuted under instructions from the Chief of Ordnance, U. S. Army, as a preliminary to the construction of the gun. In the section selected for the test the wall of the gun (see Plate IV) comprises the following parts, viz: The tube, 2.25 inches; the jacket, 4 inches; the inner (A) hoop, 2.15 inches, and the outer (B) hoop, 2.6 inches in thickness. The diameter of the bore (or chamber) is 9.5 inches and the exterior diameter 31.5 inches. The thickness of wall is then 1.375 calibers, expressed in terms of the caliber of the gun, and about 1.16 calibers, in terms of the diameter of the chamber. The length of the section was made 7.5 inches for the hoops, with slightly increased lengths for the jacket and tube, to prevent the last from giving way at its unsupported ends, and with the intent to equalize the diametrical changes of dimensions throughout the length of each of the elementary cylinders.

THE METALS USED IN THE CONSTRUCTION.

The metals composing the elementary cylinders employed in this experimental construction were of the same manufacture as those intended to be used for the corresponding parts of the gun for which the tube, jacket, and trunnion hoop have been manufactured by Whitworth, and all the remainder of the hoops by the Midvale Steel Company, Nicetown, Pa. The orders for the steel forgings for the gun included two cylinders, 24 inches in length, of cross-sections corresponding to the tube and jacket, and to be treated in the same way as the larger pieces. The experimental tube and jacket cylinders were cut from one end of these cylinders, and the test pieces for the free tests of the metal were taken inside of these or near the middle of the forging. The forgings for the tube and jacket of the gun, manufactured at the same time with these cylinders, were rejected under tests made upon specimens of metal taken from their breech ends, where, as has since been shown, the metal was locally injured, probably by overheating in the annealing process subsequent to the oil-tempering.* But the tests of the extra forgings showed them to be of an average quality which would permit their use for the purposes of the present experiment.

The two hoops marked A*x* and B*x* were taken from the whole lot of hoops made for the gun by the Midvale Company. The tests made of the metal of these hoops showed them to possess the excellent uniform quality common to the remainder of the lot. These two hoops were rolled†, oil-tempered, and subsequently annealed.

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* See foot-note to page 10, Report of the Chief of Ordnance, U. S. Army, 1884. New forgings for the gun tube and jacket, since supplied by Whitworth, have been found satisfactory.

† The smaller hoops for the portion of the gun forward of the trunnions were forged and not rolled, but the tests of the metal show them to be of practically the same quality as the rolled hoops.

Physical properties of the metals before and after the hooping test.—Original tests were made of specimen bars cut from the several forgings to ascertain the physical qualities of the metals for use in computing the shrinkages to be used in the experimental hooping test, and to determine the fitness of the metals for the purposes of the construction. Subsequent tests were made of bars cut from each of the elementary cylinders following the dismantling of the experimental section, in order to determine the effect of the intermediate operations upon the physical qualities of the metals.* All of the *tests* were made upon the United States testing machine, at Watertown arsenal, Massachusetts.

Plate I shows the positions of all the specimens for tests by both tension and compression taken from the tube and jacket cylinders; in Figs. 2 and 4 those for the tube before and after the hooping, respectively, and in Figs. 1 and 3 those for the jacket similarly arranged.

The metal of the hoops was subjected to tests by tension only corresponding to the important part of their duty in the gun. Anticipating, however, from previous experiments that the hooping test and incidental operations would bring about a degradation of the tensile qualities of the hoop metal, special tests of bars, in addition to the usual ones, were made from the metal of the outer hoop. Six specimens (see Fig. 3, Plate II) were taken from this hoop following the hooping test. The alternate numbers B E X, 1, 3, and 4 were first tested in the usual way. Afterwards the remaining three, B E X, 2, 5, and 6, were first subjected to a sudden stress of 58,000 pounds per square inch, which exceeded by about 2,000 pounds per square inch the elastic limit found for the first three specimens, and were then tested in the usual way. The sudden stress was applied five times to each specimen at intervals of ten minutes between the applications. Each application of the stress occupied about two seconds of time. The object of these special tests was to ascertain the behavior of the metal following its subjection to the hooping test under circumstances assimilated as nearly as possible to those attending the actual firing of the gun, and to find (supposing its elastic limit to have been lowered by the hooping test) to what extent its loss of elastic strength would be restored.

Plate II shows the positions of specimens taken from the hoops: in Figs. 1 and 2 before the hooping test, and in Figs. 3 and 4 following that test. The dimensions of the finished specimen bars as tested are shown in Plate III, Figs. 1 and 3.

In the following table the results of the tests are arranged to show the effect of progressive loads within the elastic limit, to enable the selection from the tests of original metal, of the values of the physical constants to be used in computing the shrinkages, and, by comparison with the tests made after the hooping, to show the percentages of gain or loss of the physical qualities of the metals within the limits which the metal would be called upon to work in the gun when fired.

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* The discussion of the results of these tests would in natural order follow that of the hooping test, but it seems better to place it here in order to make direct comparison with the tests of the original metal, and present at once the conclusions which these tests of the metal enable to be drawn regarding the effect of the hooping operations upon the physical qualities of the metal.

TABLE I.—*Elastic properties and strength*

Tests of—	Specimen.			Relative elastic extensions (inches) and corresponding stresses per square inch.					
	Marks.	Stem.							
		Length.	Diameter.	0.00130.	0.00135.	0.00140.	0.00145.	0.00150.	0.00155.
TUBE CYLINDER.									
By tension:				*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*
Before the hooping	A T. O.....	3.0	0.564	45,000	46,500	48,000	50,500	51,500	52,250
	B T. M.....	3.0	0.564	46,000	47,500	49,500	50,500	51,500	52,500
	C T. I......	3.0	0.564	43,350	43,850	....	....	....	....
	Means.	....	....	44,780	45,950	....	....	....	....
After the hooping.	T T 1, M....	3.0	0.564	42,000	43,500	45,000	46,500	48,000	49,500
	T T 2, I....	3.0	0.564	42,000	44,500	46,000	....	....	....
	Means	....	....	42,000	44,000	45,500	....	....	....
Mean loss percentage of original qualities....				6.2	4.3	....	....	....	....
Mean gain percentage of original qualities....				....	....	....	....	....	....
By compression:									
Before the hooping.	E. T. O......	5.0	0.798	33,575	35,000	36,425	37,850	38,575	40,3[illegible]
	D. T. I......	5.0	0.798	41,000	42,000	43,500	....	....	....
	F. R........	4.0	0.798	40,000	40,750	42,000	43,500	44,325	44,8[illegible]
	G. R........	4.0	0.798	35,000	36,500	37,500	....	....	....
	O. R........	4.0	0.798	36,000	36,750	....	....	....	....
	Means	....	....	37,115	38,190	....	....	....	....
After the hooping.	C T 1, M....	5.0	0.798	37,500	39,170	41,000	42,000	44,000	46,000
	C T 2, I....	5.0	0.798	36,500	37,500	38,500	39,500	41,500	45,000
	Means	....	....	37,000	38,335	39,750	40,750	42,750	45,500
Mean loss percentage of original qualities..				0.3	....	....	....	....	....
Mean gain percentage of original qualities...				....	0.4	....	....	....	....
JACKET CYLINDER.									
By tension:									
Before the hooping	H. T. O.....	3.0	0.564	47,000	48,250	49,500	51,500	53,000	54,500
	I. T. M......	3.0	0.564	45,000	46,500	48,000	49,250	50,000	51,500
	J. T. I......	3.0	0.564	40,000	42,500	44,000	45,500	47,000	48,[illegible]
	P. R........	2.0	0.564	42,000	43,500	45,000	46,000	47,500	[illegible]
	R. R........	2.0	0.564	42,500	44,000	45,500	47,500	49,000	50,000
	Means	....	....	44,125	44,950	46,400	47,950	49,300	50,[illegible]
After the hooping.	T J 1, O.....	3.0	0.564	41,000	42,750	45,000	46,500	48,000	....
	T J 2, M....	3.0	0.564	47,000	48,500	50,000	50,500	51,000	....
	T J 3, I....	3.0	0.564	41,000	41,750	43,000	45,500	47,000	48,500
	Means	....	....	43,000	44,335	46,000	47,500	48,665	....
Mean loss percentage of original qualities..				2.55	1.4	0.86	0.94	1.8	....
Mean gain percentage of original qualities....				....	....	....	....	....	....
By compression:									
Before the hooping.	L. T. O.....	5.0	0.798	44,000	45,325	46,000	47,000	49,000	....
	K. T. I.....	5.0	0.798	44,000	46,000	47,000	48,000	50,000	5[illegible],000
	M. R........	4.0	0.798	42,000	43,500	45,500	47,500	48,325	48,[illegible]
	N. R........	4.0	0.798	40,500	42,500	45,000	46,250	47,000	47,000
	Means	....	....	42,625	44,330	45,875	47,190	48,580	....

of the metals before and after the hooping test.

Relative elastic extension (inches) and corresponding stresses per square inch.				Elastic limit.		Ultimate resistance.		Remarks.
0.00160.	0.00165.	0.00170.	0.00175.	Load per square inch.	Extension per inch.	Load per square inch.	Extension per inch.	
Lbs.	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*	*Inches.*	*Lbs.*	*Inches.*	
53,000	......	......	......	53,000	0.0016	86,040	0.2467	After 53,000 stretched rapidly and load fell to 48,000.
54,000	......	......	......	54,000	0.0016	89,320	0.2400	After 54,000 stretched rapidly and load fell to 49,000.
......	......	......	......	44,000	0.00137	84,000	0.2000	After 44,000 stretched rapidly and load fell to 41,000.
......	......	......	......	50,330	0.001522	86,450	0.2289	
50,500	51,500	53,000	......	53,000	0.0017	91,040	0.2133	
......	......	......	......	47,000	0.00143	87,560	0.2433	
......	......	......	......	50,000	0.001565	89,300	0.2283	
......	......	......	......	0.7	......	......	0.3	
......	......	......	......	......	2.8	3.2	......	
41,000	43,000	45,000	47,000	49,000	0.0018	......	......	Rapid deflection at 50,000 pounds.
......	......	......	......	44,000	0.001425	......	......	Rapid deflection at 45,500 pounds.
45,250	45,625	46,000	46,750	48,000	0.0018	......	......	Decided deflection at 50,000 pounds.
......	......	......	......	38,000	0.00143	......	......	Gradual deflection beyond elastic limit.
......	......	......	......	37,000	0.00137	......	......	
......	......	......	......	43,200	0.001565	......	......	
47,500	48,500	49,500	51,000	53,000	0.001775	80,600	......	Triple flexure.
46,000	47,000	57,670	49,500	50,000	0.00175	78,400	......	Do.
46,750	47,750	48,585	50,250	51,500	0.001762	79,500	......	
......	......	......	......	...	......	......	......	
......	......	......	......	19.3	12.6	......	......	
55,500	56,500	58,000	59,500	60,800	0.0018	104,000	0.21	After 60,800 stretched rapidly and load fell to 57,000.
52,800	......	......	......	52,800	0.0016	93,280	0.20	After 52,800 stretched rapidly and load fell to 50,000.
49,000	50,500	52,000	53,500	59,760	0.0020	97,000	0.173	After 59,760 stretched rapidly and load fell to 56,000.
50,500	52,000	53,000	......	53,000	0.0017	100,560	0.12	
51,000	......	......	......	51,000	0.0016	91,600	0.20	
51,760	......	......	......	55,472	0.00174	97,288	0.1806	
......	......	......	......	49,000	0.001583	88,160	0.25	
......	......	......	......	51,000	0.00150	95,400	0.2167	
49,500	50,500	52,000	53,500	59,000	0.002033	107,140	0.150	
......	......	......	......	53,000	0.001689	96,900	0.2056	
......	......	......	......	4.5	2.9	0.4	......	
......	......	......	......	......	......	......	13.8	
......	......	......	......	49,000	0.0015	......	......	Rapid deflection at 50,000 pounds.
52,650	53,500	55,000	56,000	59,000	0.001775	......	......	Rapid deflection at 60,000 pounds.
50,500	52,500	54,000	56,250	57,000	0.0018	......	......	
49,000	51,500	53,000	......	54,000	0.001733	......	......	Gave suddenly at 54,000 pounds.
......	......	......	......	54,750	0.001702	......	......	

TABLE I.—*Elastic properties and strength of the*

Tests of—	Specimen.			Relative elastic extension (inches) and corresponding stresses per square inch.					
	Marks.	Stem. Length.	Stem. Diameter.	0.00130.	0.00135.	0.00140.	0.00145.	0.00150.	0.00155.
JACKET CYLINDER—Continued.									
By compression:				*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*
After the hooping	C J 1, O.....	5.0	0.798	46,000	48,000	49,500	51,000	52,000	53,500
	C J 2, M...	5.0	0.798	42,000	43,000	44,000	45,000	46,000	47,750
	C J 3, I...	5.0	0.798	37,860	39,285	41,000	42,500	44,000	46,000
	Means.............			41,955	43,430	44,865	46,165	47,335	49,065
Mean loss percentage of original qualities...				1.06	2.0	2.2	2.17	2.55	
Mean gain percentage of original qualities ..				....	....	......	.... ..		
A HOOP.									
By tension:									
Before the hooping	R A x 2, O..	6.0	0.564	42,000	44,000	46,500	47,665	49,000	50,000
	R A x 1, I ..	6.0	0.564	45,000	46,665	48,600	49,560	52,000	53,000
	R A x 4, O..	3.0	0.564	47,500	48,500	51,000	53,500	55,000	56,500
	R A x 3, I ..	3.0	0.564	43,500	45,500	47,500	48,500	50,000	51,500
	Means			44,500	46,165	48,250	49,790	51,500	52,750
After the hooping	A E X 1, M	6.0	0.564	40,000	41,500	43,000	44,500	46,330	47,500
	A E X 2, I	6.0	0.564	42,000	43,500	45,000	46,500	48,000	49,000
	A E X 3, M	6.0	0.564	38,750	41,000	43,250	44,000	45,330	47,600
	Means			40,250	42,000	43,750	45,000	46,555	47,835
Mean loss percentage of original qualities...				9.55	9.02	9.33	9.62	9.41	9.32
Mean gain percentage of original qualities....				.. ...	....	....	....	....	....
B HOOP.									
By tension:									
Before the hooping	R B x 2, O..	6.0	0.564	44,000	46,000	47,330	48,500	49,650	51,350
	R B x 1, I...	6.0	0.564	43,500	46,000	47,000	48,000	49,500	51,350
	R B x 4, O.	3.0	0.564	43,000	45,500	47,000	47,750	49,000	51,500
	R B x 3, I..	3.0	0.564	42,500	46,250	47,000	48,500	49,500	50,250
	Means.............			43,250	45,935	47,080	48,185	49,410	51,110
After the hooping	B E X 1, O..	6.0	0.564	42,000	44,000	45,330	46,500	48,000	49,000
	B E X 3, O..	6.0	0.564	40,000	41,500	43,000	44,330	45,330	46,500
	B E X 4, I ..	6.0	0.564	40,000	42,000	44,000	45,000	46,665	47,500
	Means.............			40,665	42,500	44,110	45,275	46,665	47,665
Mean loss percentage of original qualities....				5.98	7.48	6.31	6.04	5.55	6.74
Mean gain percentage of original qualities....				.. .	.. ...	......	....	....	....
By tension, after the hooping. Special.	B E X 2, I..	6.0	0.564	36,365	37,730	38,100	40,420	41,690	42,900
	B E X 5, O..	6.0	0.564	37,500	38,750	40,000	41,250	42,500	43,750
	B E X 6, I ..	6.0	0.564	36,625	38,075	39,230	40,420	41,670	42,980
	Means.............			36,930	38,185	39,110	40,695	41,955	43,210
Mean loss percentage of original qualities ..				14.6	16.9	16.9	15.5	15.1	15.5
Mean gain percentage of original qualities....				....	....	....	.. ..	....	....

NOTE.—The terminal letters above have the following signification, *metals before and after the hooping test*—Continued.

Relative elastic extension (inches) and corresponding stresses per square inch.				Elastic limit.		Ultimate resistance.		Remarks.
0. 00160.	0. 00165.	0. 00170.	0. 00175.	Load per square inch.	Extension per inch.	Load per square inch.	Extension per inch.	
Lbs.	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*	*Inches.*	*Lbs.*	*Inches.*	
55, 000	56, 000	57, 000	....	57, 000	0. 0017	88, 760	....	Triple flexure; bent 180° without fracture.
50, 000	51, 000	52, 000	53, 500	55, 000	0. 001825	87, 840	....	Do.
47, 500	49, 000	50, 000	51, 500	58, 000	0. 00195	87, 920	....	Triple flexure.
50, 835	52, 000	53, 000	....	56, 665	0. 001825	88, 175	....	
....	....	....	....	...	....	....	....	
....	....	....	..	3. 5	7. 2	....	....	
52, 000	52, 750	54, 000	55, 600	62, 000	0. 002017	107, 200	0. 1667	
54, 500	57, 000	58, 500	60, 500	62, 000	0. 001783	107, 280	0. 1317	
57, 500	58, 500	60, 000	62, 500	66, 000	0. 001967	109, 240	0. 1767	
53, 000	54, 500	56, 000	57, 500	65, 000	0. 002067	105, 200	0. 1933	
54, 250	55, 690	57, 125	59, 000	63, 750	0. 001958	107, 230	0. 1673	
49, 000	50, 000	52, 000	53, 665	57, 000	0. 001833	100, 440	0. 1667	
51, 000	52, 500	53, 665	55, 200	59, 000	0. 001833	99, 680	0. 1633	
48, 665	50, 000	51, 500	53, 330	61, 000	0. 002050	103, 160	0. 1800	
49, 555	50, 835	52, 390	54, 065	59, 000	0. 001939	101, 093	0. 1700	
8. 65	8. 72	8. 29	8. 36	7. 45	0. 97	5. 72	....	
......	....	......	....	....	....	...	1. 6	
52, 350	53, 500	55, 000	....	55, 000	0. 0017	101, 840	0. 1567	
52, 250	53, 000	54, 500	56, 000	58, 000	0. 001833	103, 280	0. 16	
53, 000	54, 500	55, 500	56, 250	60, 000	0. 001933	104, 000	0. 1867	
51, 000	52, 500	55, 000	56, 500	61, 000	0. 001933	104, 360	0. 1867	
52, 150	53, 375	55, 000	....	58, 500	0. 00185	103, 370	0. 1725	
50, 500	52, 000	53, 000	54, 330	55, 000	0. 001783	100, 440	0. 1417	
48, 000	50, 000	51, 250	52, 000	55, 000	0. 001850	98, 440	0. 1500	
48, 500	50, 000	51, 500	53, 500	57, 000	0. 001900	100, 080	0. 1450	
49, 000	50, 665	51, 915	53, 275	55. 665	0. 001844	99, 653	0. 1456	
6. 04	5. 08	5. 61	....	4. 85	0. 3	3. 6	15. 6	
....	....	. ...	....	....	....	....	....	
44, 200	45, 360	46, 430	47, 500	63, 000	0. 002583	98, 800	0. 1300	Subjected first to a sudden stress of 58,000 pounds per square inch, applied five times at intervals of ten minutes, each application taking about two seconds of time. Finally tested in the usual way by progressive loads applied intermittingly.
45, 000	45, 940	46, 880	47, 820	63, 000	0. 002517	97, 200	0. 1700	
44, 170	45, 420	46, 670	47, 920	63, 000	0. 002617	100, 160	0. 1333	
44, 455	45, 575	46, 660	47, 745	63, 000	0. 002572	98, 720	0. 1444	
14. 8	14. 6	15. 1	....	.... .	....	4. 5	16. 3	
....	......	....	....	7. 7	39. 1	....	....	

viz: T, tangential; R, radial; O, outside; M, middle; I, inside.

Values of the physical constants.—In selecting these values to be substituted for the constants in the formulas applied for determining the shrinkages for the experiment it is observed that the tests of the different specimens of the original tube metal show great irregularity of elastic strength, and the specimens both for that and the original jacket metal failed notably after reaching a stress exceeding but little the so-called elastic limit. Then as the tube and jacket would have principally to withstand compression only in the hooping test, a greater value is attached to those tests, and finally those values have been selected under which all of the compression specimens showed perfect, or nearly perfect, elasticity. With regard to the hoops the values given below are based generally upon the results of tests of specimens from the whole lot of hoops made for the gun, including the hoops A*x* and B*x*, given above.

The following are the values adopted :*

Subject of measurement.	Tube.	Jacket.	Hoops.
Allowable displacement per linear unit.... inches	0.00135	0.0015	0.00175
Corresponding load per square inch :			
Pounds	38,200	48,750	56,000
Tons	17.035	21.736	25.0
Moduli of elasticity :			
Pounds	28 300,000	32,500,000	32,000,000
Tons	12,634	14,509	14,286

Effect of the hooping test upon the physical qualities of the metals.—Examining the individual records of the bars tested after the hooping, we find no reason to suspect a local imperfection in the metal which might have lowered the record, except possibly for the tension specimen T J_1, from the outside of the jacket; for the rest the percentages of "gain" or "loss" shown are sufficiently marked to enable well-grounded deductions to be made in several particulars regarding the effect of the hooping test upon the physical qualities of the metals.

(1) The elastic limit of the tube metal under compression was markedly elevated both in respect to the stress supported and the elastic displacement; the respective percentages of "gain" are 19.3 and 12.6, and it will also be observed from the column of remarks that the two specimens failed by triple flexure instead of showing a failing point, as in the tests of the original metal. Fig. 5, Plate III, shows the form of one of these specimens after the test.

(2) The qualities of the jacket metal under compression were also improved, for while this metal shows a "loss" in respect to the load supported under relative displacements between 1.3 and 1.5 thousandths, yet at the elastic limit it shows a gain of 3.5 per cent in the load supported and of 7.2 per cent. in elastic displacement, and still better proof is given by a comparison of the manner in which the specimens stood the test. One of these specimens, which was bent 180° without fracture, is represented in Fig. 6, Plate III.

(3) The metal of both the hoops shows a clear loss of tensile qualities. With the A hoop this loss varies from 9.62 per cent. in the load supported under an extension of 1.45 thousandths to 7.45 per cent. at the elastic limit, and with the B hoop there is similarly a loss varying from 7.48 to 4.85 per cent. This decrease in the load supported for a

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*For the subsequent use of these values and computation of the shrinkages see Notes on the Construction of Ordnance, No. 31.

given extension carries with it a corresponding decrease in the modulus of elasticity.*

Respecting the qualities of the tube and jacket metal under tension there is little or no change. We judge from the record, however, that the tensile qualities of the latter metal are slightly impaired notwithstanding the doubt resting upon the specimen $T\ J_1$; aside from this the records of the specimens are broken after passing the extension 1.5 thousandths, whilst under the tension tests of the original metal all the specimens passed the extension 1.6 thousandths.

We have now to consider the results of the special tension tests made of the B-hoop metal. It will be seen at once that the results of these tests are highly reassuring. The special elastic limit developed is the same for each specimen and equal to 63,000 pounds per square inch. Not only is the loss of original qualities counterbalanced by sudden strains assimilated to those which the metal will undergo in firing the gun, but the load originally supported at the elastic limit is raised 7.7 per cent. and the elastic stretch is raised 39 per cent. The loads for given stretches within the elastic limit are decreased and thus also the modulus of elasticity, but the subjection of the metal to the sudden strains has increased its capacity to perform work and has thereby certainly not diminished its utility in the gun structure.

The further conclusions to be drawn from these comparisons are that in considering the properties of metal tested for gun construction with reference to its behavior in the structure we may expect the tube to possess higher qualities than shown by the tests, the jacket to remain about neutral, and the hoops to possess a decreased elastic strength, and for the particular structure under consideration the qualities of the hoops should be estimated at about 10 per cent. below those determined by the tests of detached specimens. The loss of strength in the hoops is evidently due to the fact of their being forcibly restrained from resuming their original dimensions whilst cooling from a heated state.† This loss is shown to be not excessive and also (from the special tests given) apparently not dangerous for the service of the gun, but it is

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* In confirmation of these results we refer to the following, which have not been found heretofore reported, owing to the fact that they were not available when the report in question was rendered. They refer to the shrinkage tests of Midvale steel hoops No. 9018 and 9020 (see Notes on the Construction of Ordnance No. 25). Tests were made of specimen bars cut from these two hoops after the conclusion of the shrinkage tests. The losses and gains from original qualities shown by a comparison of the mean of these tests with those given on page 3 (note 25) are as follows:

Subject of measurement.	Hoop 9018, oil-tempered.		Hoop 9020, annealed.	
	Loss.	Gain.	Loss.	Gain.
	P. ct.	*P. ct.*	*P. ct.*	*P. ct.*
Elastic limit:				
Stress in pounds per square inch	9.33		8.65	
Relative elastic extension		3.5	2.80	
Ultimate resistance:				
Stress in pounds per square inch	6.12		4.88	
Relative extension		12.75	1.74	
Ratio of elastic to ultimate resistance	3.57		4.15	
Contraction of area at fracture		0.6	27.6	
Ultimate resistance per square inch of fractured area	5.72		12.3	

† This conclusion is simply confirmatory of the results stated by General Rosset from tests made by forcibly restraining long bars of heated steel whilst cooling. (Notes on the Construction of Ordnance No. 11, page 7.)

evident that every means should be used to avoid it. The question involves three important factors, viz: (1) the nature of the metal; (2) the amount of shrinkage employed; and (3) the heat employed, both as regards its degree and its nature. The first of these points cannot be discussed here; but the A hoop, originally possessing a higher elastic limit than the B hoop, showed a relatively greater loss than the latter, whilst the two were presumably of like metal, so that independent of the chemical composition of the metal a high development of the elastic qualities in the tempering may not be considered unmixed with evil. The two remaining points may be regulated by avoiding excessive shrinkages wherever possible and by careful, *uniform* heating to a degree not greater than that required for the assemblage.

Supplementary tests were also made for hardness of the jacket metal, which appeared under the cutting tool to be softer after it was heated and shrunk upon the tube than it was originally. The form of the test specimen is shown in Fig. 2, Plate III. Three specimens J_1, J_2, and J_3, Fig. 1, Plate I, taken from the original metal, gave the following degrees of hardness: 18.88, 20.93, and 21.29, an average of 20.37; whilst three others, J_4, J_5, and J_6, Fig. 3, taken from the cylinder, after the hooping, gave the following: 22.51, 18.19, and 19.39, an average of 20.03—showing that the effect of the shrinkage operations produced little, if any, softening of this metal.

THE HOOPING TEST.

The purpose of this experimental construction was to obtain in general such data as could be made available in the after construction of the gun; to determine the behavior of the elementary cylinders in combination under the theoretical shrinkages deduced by a rigorous application of the theories and formulas; the individual behavior of the elementary cylinders; and whether the aforesaid theoretical shrinkages should be applied in the after-construction of the gun or to what extent they should be modified for that construction.

The test is in part necessarily supplementary to the free tests of detached specimen bars, for the latter serve to determine the absolute values which represent the physical properties of the metals and become the standards of reference. The hooping test furnishes an absolute knowledge of the displacements of the fibers of the metal alone, but by means of this factor, which is common to both, we are enabled to compare the results of the two kinds of tests. In the hooping test, however, each elementary cylinder may be considered as a complete specimen bar, obedient to laws similar to those which govern the behavior of detached specimens under test, and therefore affording a more certain knowledge of the elastic displacements of the cylinder as such than can be derived from the free tests. The results of the hooping test may then be used to confirm, or possibly to modify, those determined by the free tests; that is, we may find that a given cylinder will stand the same (or perhaps a different) amount of elastic displacement as shown by the free tests of its metal.

The variety of rules and formulas applied to the construction of guns and the lack, so far as known, of concise data tending to prove or disprove the reliability of any given set of theories and formulas has led in the present experiments to an attempt to supply such data. Besides the practical knowledge applicable to the particular case in hand to be derived from this experiment an opportunity is afforded for a critical comparison of the results of theory and practice as applied to the changes of dimensions occurring in each of the elementary cylinders employed, and thus obtaining, in so far as the state of rest of the system is concerned, a knowledge of the reliability of the formulas employed which becomes of general application. The principles and formulas enunciated by Major Clavarino of the Italian army (see Notes on the Construction of Ordnance, Nos. 6 and 7), by their direct bearing upon the data obtainable in an experiment of this kind, afford, better than any others in general use, a means of making the comparison desired. This, taken in connection with their reliability as indicated by previous experiments and their general reasonableness, has led to their present adoption.*

The effect of the hooping and incidental operations upon the physical qualities of the metals has already been referred to. It is considered an important part of the investigations. In other respects this report will include, in brief, the methods employed, the results obtained, and such incidental matters of interest as have been noticed which may be of use in future work of the kind, either in extending a knowledge of the same or in helping toward more complete investigations.

MODE OF CONDUCTING THE TEST.

The general instructions prepared in advance for the guidance of the work are given in full in Appendix A, and render further description of the kind unnecessary. These instructions were varied in one particular only, namely, that the grooves *a a*, Fig. 1, Plate IV, required to be made in the end faces of the A for measuring the interior of the B hoop in place were cut before the B hoop was assembled. This change was introduced to simplify the work. It reduces the risk of injury to the interior surface of the outer cylinder and gives greater confidence in the results. When one cylinder is shrunk upon another whose outer surface it does not cover—that is, if the ends of the under cylinder project—there will be caused a slightly bell-shaped form at the interior extremities of the outer cylinder, and the end diameters will be stretched more than those within. By cutting the grooves for the measurements before placing the outer cylinder and thus not subjecting the ends of the outer hoop at all, within the limits of the grooves, to the abnormal stretch noted, it seems that a possible source of error is eliminated. However, the change made commends itself for simplification of method alone.

The results obtained from cutting the tube and jacket cylinders in two before separating them in dismantling the section were, to some extent, not satisfactory, as will be shown, and suggest the propriety in future experimental work of this kind of removing the jacket by cutting through longitudinally on one side, as was done with the hoops in the present case.

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* It may be remarked here that whilst these formulas are hereinafter shown to be fully reliable for all practical purposes in indicating the radial changes of dimensions which occur in the elementary cylinders of a compound cylinder assembled under shrinkage, they are not so as regards changes of length. But if we omit the factor

$$q=\frac{P\ R^2-P'\ R'^2}{R'^2-R^2}$$

which (page 6, Note 6) Clavarino introduces into his fundamental formulas to embody the longitudinal stress supposed to exist in all states of the system, and carry this modification to all the formulas of application, we will obtain theoretical results which will compare more closely with the practical results of the present experiments.

THE PRESCRIBED SHRINKAGES.

The theoretical values of the shrinkages prescribed as the mean values to be applied in the hooping were as follows:*

	Relative values.	Absolute values.
	Thousandths.	*Inch.*
First shrinkage	0.45833	0.0065
Second shrinkage	1.378	0.0303
Third shrinkage	1.3734	0.0361

The method by which these values were deduced is given in full in Notes on the Construction of Ordnance, No. 31, Part II, which constitutes a preliminary study of the construction of this gun confined to the section over the powder chamber, and based upon the qualities of the metal of the cylinders used in the present experiment. In deducing the shrinkage values the fundamental principles employed were those of Clavarino, but certain restrictions will be found to have been applied in the use of his formulas whereby the results were made to satisfy the strict requirements of the theories, and to this it is believed we must, in a certain measure, attribute the satisfactory comparison adduced between the results of theory and practice.

FINISHED DIMENSIONS OF THE CYLINDERS PREPARATORY TO THE ASSEMBLAGE.

The cylinders were bored, turned, and faced to the prescribed dimensions while attached by "dogs" to the face plate of an ordinary lathe, using a single cutting tool and bar. They were first rough-finished on all sides, then faced at one end and successively bored and turned to finished size before facing the opposite end. The finished surfaces were not ground or polished, but were made as smooth as possible with the cutting tool, and in some parts, where a very slight amount of metal was to be removed, were finished by using a file in place of the tool. The results of the measurements made of the finished work are given in the following table:

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*See Appendix A.

TABLE II.—*Finished dimensions of the cylinders preparatory to assemblage.*

Measurements.	Single dimensions.		Mean dimensions.										
	No.	Maximum difference in.	No.	Eccentricity.		Conicalness.		Parallelism of ends.		Pre-scribed.	Actual.	Variations in mean diameters.	
								Variations.					
				Allowed.	Actual.	Allowed.	Actual.	Allowed.	Actual.			Allowed.	Actual.
				Inch.	*Inch.*	*Inch.*	*Inch.*	*Inch.*	*Inch.*	*Inches.*	*Inches.*	*Inch.*	*Inch.*
Tube:													
Interior diameter	20	0.0012	5	0.003	0.0004	0.002	0.0006	0.0035	....	9.5	9.4991	±0.002	−0.0009
Exterior diameter	20	0.002	5		0.001		0.0012		....	14.0077	14.0069	0. −0.002	−0.0008
Length	16	0.0035	8		....		....		0.0025	7.9	7.9025	±0.01	+0.0025
Jacket:													
Interior diameter	20	0.0015	5		0.0003		0.0007		....	14.0	14.0002	±0.002	+0.0002
Exterior diameter	20	0.002	5		0.0009		0.0009		....	22.0288	22.0295	0. −0.002	+0.0007
Length	16	0.0055	8		....		....		0.0027	7.55	7.5533	±0.01	+0.0033
A hoop:													
Interior diameter	20	0.002	5		0.0005		0.0015		....	22.0	21.9975	±0.002	−0.0025
Exterior diameter	20	0.0025	5		0.0004		0.0016		....	26.3363	26.3350	0. −0.002	−0.0013
Length	16	0.0035	8		....		....		0.0027	7.5	7.4994	±0.01	−0.0006
B hoop:													
Interior diameter	20	0.0025	5		0.0012		0.0012		....	26.3	26.2992	±0.002	−0.0008
Exterior diameter	8	0.001	2		0.0003		0.0003		....	31.5	31.4981	±0.01	−0.0019
Length	16	0.0042	8		....		....		0.003	7.5	7.4951	±0.01	−0.0049
Exterior diameter of jacket before assemblage	20	0.0025	5		0.0014		0.0005	The exteriors of these two cylinders were left with diameters about 0.08 large—22″.1054 and 26″.4311 respectively for their assemblage, and were measured in this state in order to determine their extension after assemblage.					
Exterior diameter of A hoop before assemblage.	20	0.0065	5		0.0006		0.0059						

It may be observed that the allowed variations were exceeded in two cases only, viz, the exterior (mean dimension) of the jacket cylinder was turned 0.0007 of an inch too great, and the A hoop was bored 0.0005 of an inch too small. The results warrant some modification of the allowed variations prescribed by the instructions, appendix A, and permit the establishment of the following for similar gun-construction work, viz:

	Inch.
Mean eccentricity	0.002
Conicalness	0.002
Parallelism of ends	0.0035
Interior diameter (mean dimension)	±0.002
Exterior diameter (mean dimension for shrinkage)	±0.001
Length (mean dimension)	±0.005

Appendix B contains the separate measurements of dimensions made at this time and in all the subsequent stages of the experiment. All measurements were referred to a 36-inch vernier beam caliper reading to 0.001 of an inch, manufactured by Darling, Brown & Sharpe. Before the completion of the work, a set of micrometer rods, which can readily be read to 0.0005 of an inch, were received from the Frankford Arsenal. They were found to be reliable and labor-saving. When in use they were set by the standard vernier beam scale and referred to it from time to time for verification of the measurements taken.

THE SHRINKAGE OPERATIONS.

It was desired to heat the cylinders for the shrinkage in a hot-air chamber, where they would be wholly protected from contact with flame and surrounded by a uniform medium, having a temperature of from 500° to 600° Fahrenheit, in which each cylinder should remain submerged until it had attained nearly or quite the temperature of its surroundings. A hydro-pyrometer* was provided to measure the temperature of the chamber from time to time so that the degree of heat might be controlled and the expansion of the cylinders due to a given heat determined.

The nearest approach, however, to such an air-chamber that could be devised with the means at hand consisted in the use of a reverberatory heating-furnace, which was first raised to a proper degree of heat before the cylinder was put in, then closed as completely as possible and a low fire maintained. For handling, an iron carriage was arranged to run in and out of the furnace upon a couple of iron rails laid on the bottom of the latter and projecting from the door. The cylinders were placed on this and stood in the middle of the furnace for heating. The carriage could be readily run in and out, and the expansion of the cylinder was measured from time to time. When finally taken from the furnace, two inferior diameters at right angles were carefully measured, and also the length. The bore of the tube was kept filled with cold running water from the time of placing a heated cylinder until the whole section became comparatively cool. No water was applied to the heated cylinder until it had closed on the under cylinder; it was then lightly and evenly sprinkled (with a watering-pot) until its temperature became sensibly equal to that of the under cylinder. Water was then copiously applied with a hose over all until the whole was cool.

A record of the shrinkage operations is given in the following tabulated statements:

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*A description of this pyrometer, written by Lieut. C. S. Smith, United States Ordnance Department, will be frouud in the Report of the Chief of Ordnance, United States Army, for 1878, pages 374-8. It consists essentially of a copper vessel, containing, when in use, 65 cubic inches of water, an immersed thermometer, and a copper piece of 5.012 ounces' weight, which, after being heated, is submerged in the water, and the rise of temperature of the latter noted.

TABLE III.—*Shrinkage operations.*

[(*a*) **Record of hydro-pyrometer used in determining temperature of furnace.**]

In heating—	Copper piece in furnace.	Temperature of water.			Value of unit of scale.	Temperature of furnace.	Fuel consumed (coal).	Remarks.
		Original.	Final.	Rise.				
	′	°	°	°	°	°	*Pounds.*	
Jacket cylinder..	20	65.3	73 5	8.2	70.0	640	....	Before jacket was put in.
	15	64.3	73.0	8.5	70.0	660	500	After jacket was taken out.
A hoop	25	62.1	71.5	9.4	70.0	720	500	Before hoop was put in.
B hoop..........	18	62 3	74 0	11.7	70.0	880	....	Blast on, before hoop was put in.
	18	62.3	68.0	5.7	70.0	450	700	Very light blast, whilst hoop was in furnace.

[(*b*) **Record of measurements of heated cylinders.**]

Cylinders.	Temperature when taken from furnace.	Time at furnace.			Enlargement of original interior diameters.					Enlargements of original lengths.				Remarks.
		Intervals.		Total.	Limit allowed.	No. 1.	No. 3.	Mean.		Maximum.		When closed on under cylinder.		
		In.	Out.											
	°	′	′	′	*In.*	*In.*	*In.*	*In.*	(*)	*In.*	(*)	*In.*	(*)	
Jacket.....	480	15	3			0.014								Turned one-half around.
		9	4			0.027								Turned one-quarter around.
		8	3			0.035								Turned one-half around.
		3	1											
		5	......	51	0.040	0.040	0.040	0.040	2.86	0.027	3.576			
A hoop	475	11	2											Turned one-half around.
		10	3			0.055								Turned one-quarter around.
		6	......	32	0.070	0.063	0.061	0.062	2.82	0.027	3.600	0.015	2.00	
B hoop.....	450	11	2			0.026								Turned one-half around.
		15	2			0.048								Turned one-quarter around.
		14	3											
		4	......	48	0.080	0.071	0.071	0.071	0.70	0.019	2.533	0.012	1.60	

* Thousandths per linear unit.

TABLE III.—*Shrinkage operations*—Continued.

[(*c*) Record of cooling.]

Cylinders.	Maximum clearance over under cylinder.	Intervals of time.				Temperature of water.		Remarks.
		Taken from furnace until placed.	Closed on under cylinder.	Application of water stopped.	Total time.	At inlet.	In bore of cylinder.	
	Inch.	′	′	′	′	°	°	
Jacket	0.034	5	44	11	60	46.5	59.5	Cooled very slowly; could be easily moved on tube thirty minutes after placing.
A hoop	0.030	3	8	5	16	44.0	52.5	Cooled rapidly and imparted but little heat to the metal within.
B hoop	0.035	4	12	33	49	30.0	47.0	Cooled slowly when "sprinkled;" heat extended perceptibly thorugh to bore of tube.

The cylinders were uniformly expanded by the heating, see table (*b*); in two cases the separate interior diameters measured are equal, and in the third the difference is 0.002 of an inch. The respective linear expansions, 2.86, 2.82, and 2.7 thousandths per linear unit, are also uniform. And the whole, taken in connection with the observed temperatures of the furnace, shows that the cylinders were not subjected to an excessive heat.

Considering the inconveniences of the arrangements used as compared with what might be perfected in applying the principle of the hot-air chamber these results furnish conclusive evidence of the utility of that method of heating. The same certainty in the operations cannot be maintained in any mode of heating where the flame comes in contact with the metal. We may obtain satisfactory results in practice by heating with flame and removing the cylinder as soon as the requisite expansion is obtained, but in the short space of time occupied in heating a gun hoop—for an average hoop not exceeding one-half hour—the metal cannot in this way be heated uniformly to the low temperature required.

The observed temperatures are those of the furnace only; the cylinders were taken out as soon as the requisite expansion was reached. In the case of the B hoop, however, the observed temperature of 450° F., taken just before the hoop was removed from the furnace, gives very nearly the maximum temperature of the metal, for the hoop was not appreciably expanded during the last five minutes in the furnace. The temperature of the outside air at the time was 38° F., so that the rise of temperature in the metal was about 412° F. Its linear expansion by the measured diameters was 2.7 thousandths, so that there was an expansion of 0.0065534 thousandths per linear unit for each degree of heat, or of 1.39 thousandths for 212° F. This corresponds closely with accepted rules. Passing by an inverse method to determine the actual temperature of the metal of the two remaining cylinders from their observed linear expansions, we find:

For the jacket:

$$\frac{2.86}{.0065534}+43° \text{ (temperature of outside air)}=480° \text{ F.}$$

For the A hoop:

$$\frac{2.82}{.0065534}+45^{\circ} \text{ (temperature of outside air)} = 475^{\circ} \text{ F.}$$

These computed results are recorded in the table.

From this it may be concluded that a temperature of 500° F. is sufficient for ordinary shrinkages, and certainly no benefit will be derived from subjecting the metal to any considerably greater degree of heat.

The recorded length expansions of the cylinders have not the same value as those measured diametrically. A single measurement was made for each cylinder, using shop calipers, the reading being afterwards taken from the vernier scale, but the results are of practical value. It will be observed (*b*) that the length expansion at full heat was quite equal to, if not greater than, the circumferential extension for linear unit, and that in the case of the two hoops, where length measurements were taken at about the time when the heated cylinder closed on the one beneath, this relative length extension remained greater than the circumferential; since the latter, represented by the shrinkage values for the two hoops, was 1.455 and 1.3612 thousandths, respectively, against the 2.0 and 1.6 thousandths for the length extension. When the first of these hoops, after being shrunk upon the section, became entirely cold, its *contraction* in length (see Table VI) was about 0.1 thousandth, and that of the second or outer hoop about 0.2 thousandths per linear unit. There was then a decided contraction of the length, viz, 2.1 thousandths per linear unit for the A hoop and 1.8 thousandths for the B hoop between the period of clamping the under cylinder and the final state of rest This shows the necessity for a powerful end pressure upon a hoop whilst cooling, as is believed to be already the general practice in order to secure close joints. It is probable that even this end pressure, unless it were powerful enough to overcome the friction due to the shrinkage, would not secure close joints without the additional precaution of "nipping" the contact end of the hoop by an application of cold water.

The jacket cylinder was assembled with a "play" of 0.034 of an inch over the exterior of the tube. It cooled and contracted very slowly, and there was an interval of forty-four minutes before it closed on the tube. Thirty minutes after being placed it was still loose enough to be moved. This length of time should be amply sufficient to enable the assemblage of the gun tube and jacket proper by the screw connection contemplated.

It appears from these experiments that a clearance of 0.03 of an inch on the diameter is sufficient to allow in estimating the requisite expansion for assembling the parts of a gun. With this clearance the A hoop was eleven minutes in contracting to the size of the under cylinder, and with a slightly greater clearance the B hoop was sixteen minutes in contracting. This modifies but slightly the rule given in the instructions (Appendix A), which limits the expansion to between 2.5 and 3.5 thousandths of the interior diameter.

The assembled gun-section is represented in Plate IV. The scored and numbered diameters were used for determining the planes in which all the measurements were taken. The interior measurements of the cylinder in place were made in the grooves or incisions represented as cut in the end faces of the under cylinders. These measurements were made during the assemblage and dismantling of the gun-section in the order given in Appendix B.

DISMANTLING THE GUN-SECTION.

The B and A hoops were removed consecutively by cutting through longitudinally from the exterior on one side, and then wedging the sides of the cut apart sufficiently to allow the hoop to slide free from the section. The tube and jacket pieces before being separated were cut into two equal lengths; from one of these halves the jacket piece was removed in the same way as the hoops, and from the other the tube piece was removed by cutting through longitudinally on opposite ends of a diameter. This left one-half each of the tube and jacket cylinders complete for a determination of the permanent set of these cylinders when finally free.

The following is a record of certain measurements made during the dismantling. The theoretical normal pressure given is the computed pressures (see Appendix C) existing at the interior surface of the cylinder upon the commencement of the cut taken for its removal. In the case of the tube the pressure was acting upon the exterior surface.

TABLE IV.—*Record of the removal of cylinders.*

Cylinders.	Thickness of wall.		Successive contraction of cross-diameter.	Theoretical normal pressure in tons per square inch.		Width of cut at exterior.		Area of fractured metal.	Remarks.
	Original.	Successive thickness remaining.		Interior.	Exterior.	Original.	Increased.		
	Inches.	*Inches.*	*Inch.*			*Inch.*	*Inch.*	*Square inch.*	
B hoop	2.6			3.37		0.388			
		1.7					0.		
		1.43					0.005		First stretch observed.
		1.3					0.007		
		0.67					0.032		
		0.42					0.054		Commenced to give way, showing bulge underneath cut, and separating at that place from under cylinder.
		0.26					0.076		
		0.06						0.45	Broken—a clear break through bottom of cut.
A hoop	2.15			3.48		0.375			
		1.69					0.		
		1.40					0.001		First stretch observed.
		1.07					0.010		Commenced to give way, showing bulge underneath cut, and separating at that place from under cylinder.
		0.54					0.031		
		0.02					0.109	(not broken)	Cut could not be made further without injury to under cylinder.
Jacket	4.01			1.55		0.394			
		2.0					0.		
		1.5					0.		
		1.0					0.004		First stretch observed.
		0.5					0.008		
		0.25					0.0095		
		0.4					0.017	(not broken)	Cut could not be made further without injury to under cylinder.

TABLE IV.—*Record of the removal of cylinders*—Continued.

Cylinders.	Thickness of wall.		Successive contraction of cross-diameter.	Theoretical normal pressure in tons per square inch.		Width of cut at exterior.		Area of fractured metal.	Remarks.
	Original.	Successive thickness remaining.		Interior.	Exterior.	Original.	Increased.		
	Inches.	*Inches.*	*Inch.*			*Inch.*	*Inch.*	*Square inch.*	
Tube	2.25	......	......	......	1.55	......	......	......	
	......	0.75	0.0008	......	......	......	......	......	First compression observed.
	......	0.5	0.001	......	......	......	......	......	
	......	0.125	0.0015	......	......	......	......		
	......	0.04	0.003	......	......	......	......	(not broken)	Cut could not be made further without injury to interior of jacket.

By this method of removal it was expected to derive information regarding the stretch of the fibers in the "remaining thickness of metal," and also the bursting tension of this metal, which might afford useful information by comparison with the results of the free tests of the metal, but the B hoop was the only one of the four cylinders which broke naturally during the cutting; the A hoop and jacket had both to be finally broken by wedging. During the cutting, when the metal commenced to give perceptibly, the sides of the cut assumed a peculiar concave shape, and in the case of the two hoops, where the interior pressure was considerable, the metal under the cut bulged upwards when there was yet from 0.25 to 0.5 of an inch of thickness remaining. These peculiarities render the data of no avail for the purpose contemplated. But the data pertaining to increase in width of cut is of value in showing the point of "first observed stretch," and that at which the remaining metal began to give way when it may be said to have passed its limit of cohesion. The hoops were cut nearly half through before any stretch was apparent, and the jacket having to support an interior pressure of only about 1.5 tons per square inch was cut three-fourths through before the stretch became apparent. In the case of the tube subjected to a computed exterior pressure of 1.5 tons per square inch, the first appreciable compression took place with 0.75 of an inch of metal left, and the final compression, 0.03 of an inch, when one side was cut through as nearly as possible, shows that the cylinder was then sufficiently compressed to be entirely relieved from the contractile effort of the jacket.

The area of fractured metal, 0.45 square inch, in the case of the B hoop would indicate in itself a bursting tension of over 40,000 pounds, but the fracture was assisted by the abrasion of the tool and especially by the upward bulging of the thin stratum of metal.

Figs. 2, 3, and 4, Plate IV, are sketches relating to the form of cut, and in Fig. 4 is represented the bulge which took place in the metal under the cut. From the actual form assumed by the sides of the cut it will be seen that the widening could not be wholly attributed to the stretch of the uncut metal, but as the hoop stretched there was a circumferential sliding of the fibers about the middle of the wall over those beneath. The curved shape of the sides of cut can be explained by the distribution of the tension in the wall of a cylinder subjected to an interior pressure, this tension being greater at the middle and towards the interior of the wall than at the exterior.

FINAL DIMENSIONS OF THE CYLINDERS WHEN DISMANTLED.

The fact that the two hoops, although cut open on one side, resumed an essentially circular form when free led to a careful measurement of their interior diameters and lengths and to the adoption of the data thus obtained for showing their final dimensions the same as though these cylinders had been preserved entire.

A summary of these measurements, in connection with those made of the complete half cylinders of jacket and tube, is given in the following table, with the corresponding measurements of the cylinders in their original state, for comparison:

TABLE V.—*Final dimensions of the parts when dismantled.*

Measurements.	Single dimensions.					Mean dimensions.													
	No.		Maximum difference.			No.		Eccentricity.			Conicalness.			Parallelism of ends—variations.					
	Original.	Final.	Original.	Final.	Difference.	Original.	Final.	Original.	Final.	Difference.	Original.	Final.	Difference.	Original.	Final.	Difference.	Original.	Final.	Permanent set.
			Inch.	*Inch.*	*Inch.*			*Inch.*	*Inch.*	*Inch.*	*Inch.*	*Inch.*	*Inch.*	*Inch.*	*Inch.*	*Inch.*	*Inches.*	*Inches.*	*Inch.*
B hoop:*																			
Interior diameter..	20	12	0.0025	0.0025	0	5	3	0.0012	0.001	−0.0002	0.0012	0.0008	−0.0004	......	......	......	26.2902	26.3011	+0.0019
Length	16	16	0.0042	0.0045	+0.0003	8	8	......	......	......	......	......	......	0.003	0.0028	−0.0002	7.4951	7.4949	−0.0002
A hoop:*																			
Interior diameter..	20	12	0.002	0.003	+0.001	5	5	0.0005	0.0024	+0.0019	0.0015	0.0004	−0.0011	......	......	......	21.9975	21.9974	−0.0001
Length	16	16	0.0035	0.003	−0.0005	8	8	......	......	......	......	......	......	0.0027	0.0026	−0.0001	7.4994	7.4996	+0.0002
Jacket:†																			
Interior diameter..	20	12	0.0015	0.0042	+0.0027	5	12	0.0003	0.0005	+0.0002	0.0007	0.0037	+0.003	......	......	......	14.0002	13.9995	−0.0007
Exterior diameter.	20	12	0.002	0.0015	−0.0005	5	3	0.0009	0.0005	−0.0004	0.0009	0.0011	+0.0002	......	......	......	‡22.0268	22.0269	+0.0001
Length	16	....	0.0055	......	......	8	....	......	......	......	......	......	......	0.0027	......	......	7.5533	......	......
Tube:†																			
Interior diameter..	20	12	0.0012	0.004	+0.0028	5	3	0.0004	0.0002	−0.0002	0.0006	0.0038	+0.0032	......	......	......	9.4991	9.4979	−0.0012
Exterior diameter.	20	12	0.002	0.0016	−0.0004	5	3	0.001	0.0002	−0.0008	0.0012	0.0014	+0.0002	......	......	......	14.0069	14.0060	−0.0009
Length	16	....	0.0035	......	......	8	....	......	......	......	......	......	......	0.0025	......	......	7.9025	......	......

*Cut open on one side, but allowed free movement to resume original form in final measurements.

†One-half of original cylinder only in final measurements.

‡Deduced by subtracting from extended diameter "after assemblage" the extension of that diameter due to the assemblage, viz, 22.0295 —0.0027=22.0268, this being necessary because the diameter was turned off (for shrinkage fit) after the hoop was assembled.

Recollecting that the two hoops, besides being cut open whilst under strain, were also forced open by wedging, their final eccentricity, conicalness, and permanent set appears remarkably small. The only differences from original dimensions worthy of note are the eccentricity of the A hoop, now, however, a total of only 0.0024 of an inch, and the permanent set of mean interior of B hoop. This permanent set is shown by the recorded measurements to be uniform for the whole hoop, from which we infer that it was due to the natural operation of the hooping test and not influenced by the wedging, which would have abnormally increased the diameter perpendicular to the cut. Taken in connection with the results of previous hooping tests (Notes on the Construction of Ordnance, No. 25), this leads to the conclusion that there will always be a slight permanent set in the outer hoop when heat is used for the shrinkage. This also points to the facts disclosed by the tests of detached specimens made subsequent to the hooping test, viz, that the elastic and ultimate resistance of the metal to tension is lowered by the shrinkage operations.

It will be seen, however, that the A hoop and jacket, although stretched by shrinkage whilst hot, as was the B hoop, have now no permanent extension, showing that the compression to which they were subsequently subjected corrected whatever permanent set may have been induced when they were first assembled. Referring again to the tests made after the hooping test we find confirmation of the opinion that whilst the original shrinkage of a cylinder upon the outside of a system may injure the tensile qualities of the metal, this will not prevent a subsequent elevation of its property to resist an opposite strain when the same hoop is subsequently enveloped by others shrunk upon it, and in fact that a certain elevation of its qualities to resist compression is brought about under the circumstances.

The half lengths of tube and jacket show a marked and uniform conicalness or contraction towards the cut taken in dividing these cylinders whilst they were still shrunk together. The two halves which were preserved entire for final measurement are shown in position, Fig. 5, Plate IV. The tube on the diameter (*a*) away from the cross-cut has an outward set amounting to 0.0007 of an inch, whilst on (*b*), near the place of the cut, the permanent contraction was 0.003 of an inch. The final measurements for the jacket show the same form, at the outer end a permanent extension equal to 0.001 of an inch, and near the cut a permanent contraction equal to 0.0012 of an inch. Inasmuch as this form was not present before the cross-cut was made it must be due to that operation. It may in part have been caused by the inward pressure of the cutting-tool,* but is more probably due to the release of the metal near the cut from the state of tension existing at the time. Whilst shrunk together the momentary contraction in length of the jacket was 0.053 thousandths per linear unit, and the tube was extended 0.127 thousandths per linear unit, so that there existed a longitudinal as well as a circumferential state of tension. Other than the interest attached to this peculiar and somewhat inexplicable behavior, the division of the cylinders whilst still combined is to be regretted, since it throws doubt upon the final state of both as affected by natural causes due to the hooping test alone. However, the inference is fair that if either of them had been preserved entire (in length) there would have been shown a very slight, if any, permanent set. If the whole length of jacket had been removed from the tube by a longitudinal cut, as in the case of the hoops, fairly accurate data would have been obtained in regard to the effect of the hooping test upon it, whilst the tube, which on the whole may be considered the most important of the four cylinders, would have been left in perfect condition for determining the effect of the hooping test.

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*The cut was made with a tool about 0.625 of an inch wide, first from the exterior until about 1 inch thickness of metal was left, then from the interior outwards to meet the cut made from the outside.

SUMMARY OF THE RESULTS.

The table which follows embodies, in the first part, the mean dimensions of the separate cylinders for all changes of state (except the heated state) incident to the hooping test, and in the second part, the linear and proportional differences corresponding to those mean dimensions expressed in relative and absolute values. The separate single measurements from which these means are derived are given in full in Appendix B.

TABLE VI.—*Summary of results obtained in hooping experiments for 8-inch steel breech-loading rifle.*

Stages when measured.	Mean diameter.							
	Tube.		Jacket.		A hoop.		B hoop.	
	Interior.	Exterior.	Interior.	Exterior.	Interior.	Exterior.	Interior.	Exterior.
	Inches.	*Inches.*	*Inches.*	*Inches.*	*Inches.*	*Inches.*	*Inches.*	*Inches.*
Prepared for application of jacket	9.4991	14.0060	14.0002	22.1055				
With jacket applied				22.1082				
Prepared for application of A hoop	9.4955		14.0048	22.0205	21.9975	26.4311		
With A hoop applied						26.4561		
Prepared for application of B hoop	9.4907		13.9994		22.0254	26.3350	26.2992	31.4981
With jacket and A and B hoops applied	9.4862		13.9961		22.0216		26.3202	31.5257
After removal of B hoop	9.4905		13.9907		22.0237	26.3344	26.3011	
After removal of A hoop	9.4955		14.0046	22.0300	21.9974			
After removal of jacket (from half section)	9.4979	14.0060						
After removal of tube (from half section)			13.9995	22.0269				

Linear and proportional differences.	Tube, Interior, Inch.	Tube, Interior, Thousandths per linear inch.	Tube, Exterior, Inch.	Tube, Exterior, Thousandths per linear inch.	Jacket, Interior, Inch.	Jacket, Interior, Thousandths per linear inch.	Jacket, Exterior, Inch.	Jacket, Exterior, Thousandths per linear inch.	A hoop, Interior, Inch.	A hoop, Interior, Thousandths per linear inch.	A hoop, Exterior, Inch.	A hoop, Exterior, Thousandths per linear inch.	B hoop, Interior, Inch.	B hoop, Interior, Thousandths per linear inch.	B hoop, Exterior, Inch.	B hoop, Exterior, Thousandths per linear inch.
Theoretical shrinkages					0.0065	0.4583			0.0303	1.378			0.0361	1.3731		
Prescribed shrinkages:																
Maximum					0.0075	0.5300			0.0313	1.422			0.0371	1.411		
Minimum					0.0055	0.3930			0.0293	1.332			0.0351	1.335		
Actual shrinkages					0.0067	0.4786			0.0320	1.455			0.0358	1.3612		
System assembled:																
Compression of tube after application of jacket	0.0036	0.379	0.0021	0.1499												
Elongation of jacket after application					0.0046	0.3286	0.0027	0.1221								
Compression of tube and jacket by A hoop	0.0048	0.5055	0.0054	0.3855	0.0054	0.3857	0.0041	0.1861								
Elongation of A hoop after application									0.0279	1.2683	0.0250	0.9458				

Compression of tube, jacket, and A hoop by B hoop	0.0045	0.4787	0.0033	0.2356	0.0038	0.2357	0.0038	0.1705	0.0038	0.1727	0.0058	0.2202	......	......	......	......
Final compression of tube and jacket, and elongation of A and B hoops	0.0129	1.358	0.0108	0.7710	0.0041	0.2928	0.0052	0.2361	0.0241	1.0956	0.0192	0.7291	0.0300	1.1407	0.0276	1.8762
System dismantled:																
Restoration of tube, jacket, and A hoop after removal of B hoop	0.0043	0.4527	0.0036	0.2570	0.0036	0.2571	0.0041	0.1861	0.0041	0.1864	0.0052	0.1974	......	......	......	......
Restoration of tube, jacket, and A hoop on removal of A hoop	0.0050	0.5264	0.0049	0.3498	0.0049	0.3500	0.0043	0.1952	0.0283	1.2865	......	......	......	......	......	......
Restoration of jacket after removal of both hoops and of tube	......	......	......	......	0.0051	0.3643	0.0031	0.1407	......	......	......	......	......	......	......	......
Restoration of tube after removal of jacket	0.0024	0.2526	0.0014	0.1000	......	......	......	......	......	......	......	......	......	......	......	......
Final restoration of tube, jacket, and A and B hoops	0.0117	1.2317	0.0099	0.7068	0.0034	0.2428	0.0053	0.2406	0.0242	1.1001	......	......	0.0281	1.0685	......	......
Permanent "set" (compared with original dimensions)	−0.0012	0.1263	−0.0009	0.0642	−0.0007	0.0500	+0.0001	0.0045	−0.0001	0.0045	......	......	+0.0019	0.0722	......	......

TABLE VI.—*Summary of results obtained in hooping experiments for 8-inch steel breech-loading rifle*—Continued.

Stages when measured.	Mean length.			
	Tube.	Jacket.	A hoop.	B hoop.
	Inches.	*Inches.*	*Inches.*	*Inches.*
Prepared for application of jacket	7.9025	7.5533		
With jacket applied				
Prepared for application of A hoop	7.9036	7.5531	7.4994	
With A hoop applied				
Prepared for application of B hoop	7.9057	7.5547	7.4987	7.4951
With jacket and A and B hoops applied	7.9063	7,5555	7.4993	7.4937
After removal of B hoop	7.9033	7.5533	7.4972	7.4949
After removal of A hoop	7.9035	7.5529	7.4996	
After removal of jacket (from half section)				
After removal of tube (from half section)				

Linear and proportional differences.	Tube.		Jacket.		A hoop.		B hoop.	
	Inch.	Thousandths per linear inch.	Inch.	Thousandths per linear inch.	Inch.	Thousandths per linear inch.	Inch.	Thousandths per linear inch.
Theoretical shrinkages								
Prescribed shrinkages:								
Maximum								
Minimum								
Actual shrinkages								
System assembled:								
Compression of tube after application of jacket	+0.0011	0.1393						
Elongation of jacket after application			—0.0002	0.0026				
Compression of tube and jacket by A hoop	+0.0021	0.2650	+0.0016	0.2116				
Elongation of A hoop after application					—0 0007	0.0933		
Compression of tube, jacket, and A hoop by B hoop	+0.0006	0.0760	+0 0008	0.1059	+0.0006	0.0800		
Final compression of tube and jacket, and elongation of A and B hoops	+0.0038	0.4212	+0.0022	0.2912	—0.0001	0.0133	—0.0014	0.1868
System dismantled:								
Restoration of tube, jacket, and A hoop after removal of B hoop	—0.0030	0.3796	—0.0022	0.2912	—0.0021	0.2800		
Restoration of tube, jacket, and A hoop on removal of A hoop	+0.0002	0.0253	—0.0004	0.0530	+0.0024	0.3200		
Restoration of jacket after removal of both hoops and of tube								
Restoration of tube after removal of jacket								
Final restoration of tube, jacket, and A and B hoops					+0.0003	0.0400	+0.0012	0.1601
Permanent "set" (compared with original dimensions)					+0.0002	0.0267	—0.0002	0.0267

The measurements pertaining to the A hoop and B hoop, after removal, were made with the hoops cut open on one side, but allowed free movement to resume their original form. The exteriors of the hoops were not measured in this state. The final lengths of tube and jacket are omitted, since these cylinders were cut in two before being separated. The length measurements of tube, jacket, and A hoop, taken after removal of B hoop, show decidedly abnormal changes as compared with the regularity which elsewhere pervades; it must be concluded that they embody an instrumental or personal error not observed at the time of measuring, and which cannot now be determined.

Compression (—). Elongation (+).

We observe, first, that the maximum changes per unit of length to which the fibers of the metals were subjected stand as follows: Tangential compression of interior fibers of tube and jacket, respectively, 1.358 and 0.2928 thousandths; tangential extension of interior fibers of A and B hoops, respectively, 1.0956 and 1.1407 thousandths, or the momentary displacements of these fibers were, respectively, 100, 20, 63, and 65 per cent. of the displacements assumed as safe under the tests of detached specimens of the metals made before the hooping test.

The line of permanent set at the bottom of the table gives the summation of the results of the hooping test in relation to the elastic extensibility and compressibility of the cylinders under the displacements named, but in interpreting these results we must consider the various disturbing causes which have been mentioned. By giving what is considered a proper weight to these causes, the conclusion is reached that the three inner cylinders preserved their elastic properties intact, while the outer cylinder or B hoop received a slight permanent set. Practically, then, in so far as this test alone is to be judged, the cylinders of metal have shown an elastic displacement exactly commensurate with that determined by the free tests of the original metal. This conclusion is independent of the effect of the hooping test upon the physical qualities of the metals, as shown by the comparison of tests of detached specimens made before and after the hooping test, and elsewhere referred to. Considering alone the action of the cylinders, as such, the hooping test has shown that the cylinders possessed a most satisfactory uniformity of elastic strength. Its results would also indicate the propriety of using the values determined by the preliminary free tests of the metals to represent their standard physical properties without modification. The tests of metal made after the hooping show, however, that as regards the two hoops in this construction, a reduction of about 10 per cent. in the values so determined is advisable. None is needed for the tube metal, for that was strengthened by the hooping, and the essential qualities of the jacket metal were also rather improved than otherwise.

Through the intermediate changes of state the several cylinders responded evenly and uniformly to the successive pressures and reliefs from pressures to which they were subjected. The tube, which was the only one of the four cylinders not heated, but which, on the other hand, was the only one subjected to a displacement (in the section when assembled) equal to the limit assumed as safe for the metal, shows an exceptional uniformity in these intermediate changes. After the A hoop was removed, the mean diameter of the bore reverted to the precise value it had before the assemblage of this hoop. Meantime this dimension or the bore of tube had undergone four changes of form. The measurements of the interior of tube deserve special consideration, because the series is intact from the commencement of the experiment up to the division of the combined tube and jacket at the final stage. Moreover, it is the only series of the whole which, up to the period named, can be considered absolutely free from the disturbing causes introduced by the devices used throughout the experiments for taking the necessary measurements of diameters.

The data of the preceding table relating to changes in the lengths of the cylinders cannot be taken throughout with the same confidence as that relating to the diameters, for the reason that the measurements were difficult to make and because the lengths measured were relatively short. But there is no exception shown to the following, viz: A cylinder subjected to a pressure acting only upon its exterior cylindrical surface will be elongated, and, conversely, a cylinder subjected to a pressure acting only upon its interior cylindrical surface will be contracted in length. This proves the import of the two rules to the same effect given by Virgile (page 15, Notes on the Construction of Ordnance, No. 9).

In making a comparison of the relative changes in the direction of the radii and of the lengths, we have, for the case of an interior pressure, the data relating to the compression of the bore of tube in three different stages; and for the case of an interior pressure that relating to each of the three outer cylinders when first assembled.

The separate cases are summarized in the following—

Table VII.—*Comparison of relative changes of dimensions in the direction of the radii and of the lengths.*

[a. Pressure on exterior cylindrical surface alone.]

Measurements of cylinders.	Jacket applied.	A hoop applied.	B hoop applied.
	Thousandths per linear unit.	Thousandths per linear unit.	Thousandths per linear unit.
Tangential compression of bore of tube	0.379	0.8843	1.358
One-third compression of bore of tube	0.1263	0.2948	0.4527
Extension in length near bore*	0.1266	0.4433	0.5193
Mean extension in length	0.1393	0.4052	0.4812

[Pressure on interior cylindrical surface alone.]

Tangential extension of exterior of jacket	0.1221		
One-third extension of exterior of jacket	0.0407		
Contraction in length near exterior*	0.0013		
Mean contraction in length	0.0026		
Tangential extension of exterior of A hoop		0.9458	
One-third extension of exterior of A hoop		0.3157	
Contraction in length near exterior*		0.1367	
Mean contraction in length		0.0933	
Tangential extension of exterior of B hoop			0.8763
One-third extension of exterior of B hoop			0.2921
Contraction in length near exterior*			[illegible]
Mean contraction in length			[illegible]

*Refers to measurements of the length made on the circumference of a circle 0.25 of an inch from interior (or exterior). See record of measurements, Appendix B.

The theoretical rule that the length extension of the tube under its exterior pressure should equal one third of the tangential compression of the bore is practically fulfilled, only that under the application of the A and B hoops the actual length extension was somewhat greater than the one-third value. The result shows that in estimating the probable length extension of the tube of a compound cylinder a value of not less than one-third the tangential compression of the bore should be taken.

By the theory the relative length contraction of each of the three outer cylinders when assembled should have been equal to one-third the tangential extension of their exterior surface, but we find it to have been much less than this. The results are too discordant to warrant definite conclusions from this experiment except to show that there was an actual contraction which, even in the B hoop, where it is relatively the greatest, did not exceed one-fourth the relative extension of the exterior circumference of the cylinder.

Two cylinders being once shrunk together, these experiments go to prove that the two surfaces in contact will move together in subsequent elongations produced by the shrinkage of exterior cylinders. Upon the assemblage of the A hoop the exterior portion of the tube was elongated 0.0016 of an inch, and the interior portion of the jacket 0.0017 of an inch, the subsequent assemblage of the B hoop increased the above equally by 0.0008 of an inch and produced at the contact surface of A hoop on jacket an increase of 0.0008 of an inch in the length of the outer portion of the jacket, and of 0.0006 of an inch in the length of the inner portion of the A hoop. The two surfaces became one in effect from the friction between them; and when the state of things is reversed—that is, when the gun is fired and the exterior pressures here considered become interior pressures—we may expect the outer cylinders to assist materially in preventing longitudinal rupture of the inner ones if the covering is continuous without joints.*

THEORY AND PRACTICE COMPARED.

The method given, pp. 14–16, Notes on the Construction of Ordnance No. 31, has been applied in the present case, using the actual values of the shrinkages employed to make a complete analysis and comparison of the theoretical values for the changes of dimensions with the actual values given by the measurements taken in these experiments.

The comparison is arranged in the following table. The values (absolute and relative) given in the central columns (*b*) are taken from the summary table of results which precedes; those of the antecedent columns (*a*) have been computed by the method of Note 31 (see Appendix C). The values given in the third pair of columns (*c*) are also theoretical, and have been computed by a method similar to the preceding, except that the factor

$$q=\frac{PR^2-P'R'^2}{R'^2-R^2}$$

which is introduced by Clavarino to represent the longitudinal stress supposed to exist in the elementary cylinders, has been omitted from all the formulas of application.

TABLE VIII.—*Comparison of actual (measured) changes of dimensions with theoretical.*

Stages of construction-measurements.	Inches.			Thousandths per linear unit.		
	Theoretical. (*a*)	Actual. (*b*)	Theoretical. (*c*)	Theoretical. (*a*)	Actual. (*b*)	Theoretical. (*c*)
FIRST STAGE—ASSEMBLAGE OF JACKET.						
Measurements of diameters.						
Bore of tube	−0.0036	−0.0036	−0.0036	−0.379	−0.379	−0.376
Exterior of tube	−0.0030	−0.0021	−0.0034	−0.2152	−0.1499	−0.24066
Interior of jacket	+0.0037	+0.0046	+0.0031	+0.2634	+0.3286	+0.2379
Exterior of jacket	+0.0027	+0.0027	+0.0027	+0.1211	+0.1221	+0.1202
Measurements of length.						
Tube	−0.0006	+0.0011	+0.0010	−0.0757	+0.1393	+0.1253
Jacket	+0.0002	−0.0002	−0.0003	+0.0242	−0.00265	−0.0400

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* The utility of polishing the surfaces of contact is doubtful; the longitudinal friction is an important factor, and if the shrinkage surfaces are tool-finished, straight, and true, with a sufficiently smooth surface to admit of the necessary accuracy of measurement, it would appear that any further finish is at the least unnecessary.

TABLE VIII.—*Comparison of actual (measured) changes of dimensions*—Continued.

Stages of construction-measurements.	Inches.			Thousandths per linear unit.		
	Theoretical. (*a*)	Actual. (*b*)	Theoretical. (*c*)	Theoretical. (*a*)	Actual. (*b*)	Theoretical. (*c*)
SECOND STAGE—ASSEMBLAGE OF A HOOP.						
Measurements of diameters.						
Bore of tube	- 0.0086	-0.0084	-0.0086	-0.911	-0.8843	-0.904
Exterior of tube	-0.0073	-0.0075	-0.0081	-0.5177	-0.5354	-0.5786
Interior of jacket	-0.0005	-0.0008	-0.0014	- 0.0390	-0.0571	-0.1[illegible]
Exterior of jacket	-0.0013	-0.0014	-0.0025	-0.0612	-0.0639	-0.11[illegible]
Interior of A hoop	+0.0280	+0.0279	+0.0268	+1.2725	+1.2687	+1.2179
Exterior of A hoop	+0.0250	+0.0250	+0.0250	+0.9472	+0.94583	+0.9479
Measurements of length.						
Tube	-0.0014	+0.0032	+0.0024	-0.1822	+0.4053	+0.3012
Jacket	-0.0006	+0.0014	+0.0010	-0.0763	+0.18535	+0.1278
A hoop	+0.0014	-0.0007	-0.0024	+0.1895	-0.09334	-0.3157
THIRD (FINAL) STAGE—ASSEMBLAGE OF B HOOP.						
Measurements of diameters.						
Bore of tube	-0.0132	-0.0129	-0.0131	-1.390	-1.358	-1.3791
Exterior of tube	-0.0111	- 0.0108	-0.0124	-0.7899	-0.7710	-0.[illegible]
Interior of jacket	-0.0044	-0.0041	-0.0057	-0.3112	-0.2928	-0.4045
Exterior of jacket	- 0.0049	- 0.0052	-0.0072	-0.2252	-0.2361	-0.3[illegible]
Interior of A hoop	+0.0244	+0.0241	+0.0221	+1.1083	+1.0936	+1.[illegible]
Exterior of A hoop	+0.0213	+0.0192	+0.0199	+0.8050	+0.7291	+0.75[illegible]
Interior of B hoop	+0.0321	+0.0300	+0.0307	+1.2190	+1.1407	+1.1[illegible]
Exterior of B hoop	+0.0285	+0.0276	+0.0285	+0.9046	+0.8762	+0.9044
Measurements of length.						
Tube	-0.0022	+0.0038	+0.0036	-0.278	+0.4812	+0.4597
Jacket	-0.0013	+0.0022	+0.0021	-0.1667	+0.2912	+0.27[illegible]
A hoop	+0.0007	-0.0001	-0.0012	+0.0981	-0.0133	-0.1094
B hoop	+0.0014	-0.0014	-0.0023	+0.18092	-0.1868	-0.3015

NOTE.—The theoretical relative values for radial changes are computed from the prescribed diameters, viz: $D_0 = 9''.5$; $D_1 = 14''.0$; $D_2 = 22''.0$; $D_3 = 26''.3$; $D_4 = 31''.5$, in connection with the following actual shrinkage values employed in the construction, viz:

Jacket, absolute, 0.0067 of an inch; relative, 0.4786 thousandth per linear inch.
A hoop, absolute, 0.032 of an inch; relative, 1.4547 thousandths per linear inch.
B hoop, absolute, 0.0358 of an inch; relative, 1.3612 thousandths per linear inch.

The coincidence of all these results as regards *radial* changes of dimensions which directly concern the tangential resistance is remarkable and sufficient to establish confidence in the practical reliability of the formulas used for computing the shrinkages and the tangential resistance of a gun.* The most weight should be attached to the comparisons at "bore of tube," and at the exterior of each cylinder as assembled, because the actual measurements taken at those surfaces are complete for the whole length of cylinder, whilst the remaining diametrical measurements were taken only within the ends of the cylinders and may be slightly affected by causes which have been mentioned. The theoretical values for compression of the bore of tube are the same as the actual in the "first stage," but gain slightly on the latter towards the final stage, which may be taken as indicative of the increasing resistance of the tube metal to compression. (Comparison of tests of detached specimens of the metal made before and after the hooping test, Table I.) On the other hand, the comparisons at the outside surfaces named do not indicate the weakening of the elastic properties of the metal of these cylinders, which the after tests of the metal prove to have been brought about by the shrinkage operations, and this in itself is satisfactory as detracting from the apparent seriousness of that weakening.

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*By this is meant the limiting interior pressure to which a gun should, for safety, be subjected when first fired. It is believed that a gun made of steel may be strengthened by the firing, if it is not too severely strained at first. Witness the increased capacity to perform work induced even by the excessive, sudden strain to which the three specimens of the B hoop metal were subjected. (Table I.)

Considering the changes in lengths alone the comparisons show badly for the values deduced by Clavarino's theories, without modification, which give in every case a contrary sign from the actual; that is, they indicate a contraction where there was an actual extension and an extension where there was an actual contraction. But for the remaining set of theoretical values, columns (*c*) determined from his theories as modified by neglecting the longitudinal stress, the comparisons with the actual changes of length show probably as exact a coincidence as could be expected from the accuracy of the experiments. This, however, does not detract from the practical utility of Clavarino's formulas as given (Notes on the Construction of Ordnance, Nos. 6 and 7) for computing the shrinkages and tangential resistance of a gun. The omission of the factor embodying the longitudinal stress has but little effect upon the diametrical changes of dimensions.*

SHRINKAGES FOR THE CONSTRUCTION OF THE GUN.

Upon this subject, in conclusion, the results of these experiments may be considered to have supplied the necessary data. It has been shown, first, that the preliminary free tests of the metals determine suitable values for the physical constants to be used in the computations; and, second, conjointly with the above, that the formulas applied can be relied upon to indicate with accuracy the results which will be obtained in practice. These facts, in connection with the results obtained from tests of detached specimens of the metal subsequent to the hooping tests, which are, in brief, that the operations of the shrinkage tend to increase the effective resistance of the tube, and, probably, also that of the jacket, but to decrease that of the two hoops, place the question of the shrinkages in a clear way to be decided upon theoretical considerations, based upon the results of the preliminary free tests of the metals used in the construction of the gun. The limitations will be, to reduce the maximum tangential tension, or the values of θ, for the hoops about 10 per cent., and, in addition, to make the shrinkages, especially for the outside row of hoops, as light as may be found consistent with a retention of the maximum resistance demanded for the service of the gun. It is recommended to favor the outer shrinkage where practicable, because the outside cylinder forms the exterior support of the structure, and, other things being equal, the shrinkage operations should produce less degradation of the physical properties of the metal of this cylinder in proportion as reductions are made in the degree of heat required for its assemblage and the amount of constraint brought to bear upon it whilst it is cooling.

R. BIRNIE, Jr.,
Lieutenant of Ordnance.

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* Virgile neglects this factor in computing the tangential resistance, and has also agreed to neglect it in computing the shrinkages. (Page 24, Notes on the Construction of Ordnance, No. 10.) The form under which Clavarino introduces it seems difficult to defend, except, apparently, as an expedient to embody approximately the value of the longitudinal stress which is *especially* developed in the act of firing the gun. Other failing cases besides those in regard to changes of length, as given above, will be found in applying Clavarino's formulas to *special* cases, because of his introduction of this factor embodying the longitudinal stress.

APPENDIX A.

GENERAL INSTRUCTIONS FOR ASSEMBLING AND DISMANTLING AN EXPERIMENTAL COMPOUND CYLINDER—8-INCH B. L. STEEL RIFLE (DOUBLE HOOPED.)

A compound cylinder, representing a complete section of the gun over the powder chamber, not less than 7.5 inches in length, will be assembled and subsequently dismantled.

The purpose of the experiments is to test the qualities of the metal of the several cylinders composing the built-up section of the gun and to determine whether the prescribed *shrinkages* herewith, which have been theoretically deduced by the application of Clavarino's formulæ*, shall be applied in the after construction of the gun, or to what extent they should be modified for that construction.

Observations will be made to include—

(1) *All changes of radial dimensions (interior and exterior), as compared with the original, for each of the simple cylinders employed.*

(2) *All changes of longitudinal dimensions for the same cylinders.*

The results of the measurements made for determining these changes of dimensions will be recorded in relative and in absolute values; that is, in terms of the changes per linear inch and in terms of the absolute changes from total original dimensions.

The cylinders will be heated to produce the expansion necessary for their assemblage, and, if practicable, the maximum temperature which each attains will be ascertained by a pyrometer. The measurements for exact dimensions of the cylinders in their heated state will be made with all possible accuracy to include two interior diameters at right angles to each other and at least one measurement of the length.

The *interior* diameters of all the cylinders and the exterior diameter of the *outer* cylinder will be finished at the outset and the ends faced to form planes perpendicular to the axis of the bore.

The exterior diameter of the inner cylinder will next be turned to finished size for the assemblage. The exterior diameters of the second or jacket cylinder and of the inner hoop will be left 0.08 of an inch surplus over the diameter corresponding to the shrinkage prescribed, and after being assembled the change of this diameter will be measured before the exterior is turned for the shrinkage fit.

Designate the four cylinders, counting from the interior, as the tube, jacket, A hoop, and B hoop, respectively.

The values of the shrinkages to be applied are as follows:

TABLE I.

Shrinkages.	Jacket.		A hoop.		B hoop.	
	Thousandths per linear unit.	Inches.	Thousandths per linear unit.	Inches.	Thousandths per linear unit.	Inches.
Theoretical (mean values)	0.45833	0.0065	1.378	0.0303	1.3734	0.0361
Prescribed limits { maximum	0.530	0.0075	1.422	0.0313	1.411	0.0371
Prescribed limits { minimum	0.386	0.0055	1.332	0.0293	1.335	0.0351

The *limiting* values here given are based upon an allowed variation of 0.002 of an inch in the absolute values of the shrinkages; that is, in the *difference* between the several interior diameters first finished and measured and the corresponding exterior diameters upon which they are to be assembled.

DIMENSIONS OF THE CYLINDERS.

In preparing the several cylinders for assemblage the finished dimensions will be as follows:

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* See "Notes on the Construction of Ordnance," Nos. 6 and 7; also, No. 31.

TABLE II.

Measurements.	Tube.	Jacket.	A hoop.	B hoop.
	Inches.	*Inches.*	*Inches.*	*Inches.*
Interior diameter	9.5	14.0	22.0	26.3
Exterior diameter	......	22.11*	26.42*	31.5
Length	7.8	7.55	7.5	7.5

* About 0.08 of an inch surplus being left over mean diameter prescribed for the shrinkage in order to determine extension of exterior, and also to leave sufficient metal for the finish.

The allowed variation on these diameters will be ± 0.002 of an inch, and on the lengths ± 0.01 of an inch.

Before the successive assemblage of the parts the exterior diameters of the three inner cylinders must be turned to the following dimensions, with the allowed variation of + 0.000 inch and — 0.002 inch, viz:

Exterior of tube, 0″.0075 + 14′.0 corrected for error made in boring jacket.

Exterior of jacket (assembled), 0″.0313 + 22″.0 corrected for error made in boring A hoop.

Exterior of A hoop (assembled), 0″.0371 + 26″.3 corrected for error made in boring B hoop.

The following variations in measurements will be allowed in respect to parallelism of the ends and eccentricity and conicalness of the curved surfaces of the cylinders:†

	Inches.
For parallelism	0.0035
For eccentricity	0.003
For conicalness	0.002

In dismantling the section the B hoop will first be cut longitudinally from the exterior until separation takes place. The area of fractured metal, and also the amount by which the two edges of the cut separate, will be noted. The A hoop will be removed in a similar manner. Before separating the jacket and tube the two cylinders together will be cut into two equal lengths, from one of which the jacket piece will be cut off, as in the case of the hoops, and from the other the tube-piece will be cut out, and the same observations in respect to fractured surface and cut will be made. The complete half cylinders of jacket and tube will be measured to determine the residual or permanent set of these parts.

MODE OF EXECUTING HOOPING.

The tube prepared for hooping is to be supported vertically, the bore closed at bottom and made water-tight, except for a small orifice at the center of the base for the exit of the cold water with which the bore is to be kept filled during the operation. The cylinders should preferably be heated for the application in a hot-air chamber.‡ Care should be taken to have them uniformly heated and to avoid raising their temperature too high. A temperature of from 500° to 600° F. will suffice, and the expansion of the cylinder should be kept within from $\frac{2.5}{1000}$ to $\frac{3.5}{1000}$ of the interior diameter.§

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† See Notes on the Construction of Ordnance, No. 5 and of No. 25, pp. 17 and 19.

‡ Where gas is available a modification of a tire-heating machine using this frule has been found to afford superior advantages for the work, as proved in the recent construction of a 12-inch muzzle-loading rifled mortar at the South Boston Iron Works.

§ This will fix the dimensions of the gauge-rods for testing the expansion of the several cylinders under heat as follows:

Jacket	minimum	14″.035	14″.04	Approximate means.
	maximum	14″.049		
A hoop	minimum	22″.055	22″.07	
	maximum	22″.077		
B hoop	minimum	26″.366	26″.38	
	maximum	26″.392		

The cylinder should be removed from the heat as soon as the mean expansion here indicated is reached. The cylinder must be brushed clean when taken from the heat, and then placed centrally upon the tube. The transfer should be effected without unnecessary delay, as the cylinder will cool and contract rapidly. As soon as the cylinder has cooled down so as to clamp the one within it, water should be sprinkled upon it—sparingly at first, but by degrees more plentifully—care being taken to cool it uniformly.

Except for the measurements before indicated to be taken at the period of maximum heat, all measurements will be delayed at least twenty-four hours after the application of a cylinder. The following measurements are prescribed for the metal in a cold state:

(1) Original interior and exterior diameters and lengths of the cylinders, as given in Table II.

(2) Exterior of tube prepared for shrinkage.

(3) Exterior of jacket after application.

(4) Interior and exterior diameters and lengths of tube and jacket when prepared for shrinkage of a hoop.

(5) Exterior of a hoop after application.

(6) Interior and exterior diameters and lengths of tube, jacket, and a hoop when prepared for shrinkage of B hoop.

(7) Interior and exterior diameters and lengths of all the cylinders after application of B hoop.

(8) Interior and exterior diameters and lengths of tube, jacket, and A hoop after removal of B hoop.

(9) Interior and exterior diameters and lengths of tube and jacket after removal of A hoop.

(10) Interior and exterior of jacket (in the half section) after removal of tube.

(11) Interior and exterior of tube (in the half section) after removal of jacket.

MODE OF EXECUTING MEASUREMENTS.

(1) *Preparatory to the assemblage.*—Each face of cylinders will be scored with four diameters, dividing the circumference into octants, and one extremity of each diameter will be numbered. Coincident with these scores four diameters, both interior and exterior, will be measured at points corresponding to 0.1 of an inch within the position of the face of the hoops in place and at such additional points as may be necessary for ascertaining the mean diameter and verifying the workmanship. All measurements will be made in the planes determined by the scores. Two measurements for length will be made near the extremities of each scored diameter at 0.25 of an inch from the interior and exterior surfaces of the cylinder.

(2) *After cylinders are in place.*—The diameter of bore of tube and exterior diameter of jacket or hoop (as the case may be), and also the lengths, will be measured as before, the four diameters scored on faces of cylinders being radially coincident. (Care must be taken to arrange them so when the assemblage is made.) For measuring the interior diameters of jacket and of hoops, short shallow grooves are made in each face of tube and subsequently in jacket and A hoop of just sufficient size to expose the extremities of the diameters before measured at 0.1 of an inch within the faces of the hoops in place and to allow room for manipulating the points of the vernier calipers. For this purpose the dimensions of the groove should be about 0.75 of an inch wide, and in depth extend 0.1 of an inch at least within the extremities of the diameter to be measured. These grooves are made by drilling holes near the exterior surface of the cylinder and finishing the cavities with a hand-chisel. The film of metal between drill-holes and inner surface of the adjacent cylinder is left to be taken out last. A skillful workman must be employed, and great care exercised not to injure the interior surface of the adjacent cylinder. It was found best in the course of the experiments to make the grooves before assembling the outer cylinder.

(3) *After cylinders are removed.*—The same measurements will be repeated as before upon the cylinders or parts not destroyed, except that the measurements of exterior diameters near the ends will be made at points just beyond the grooves; and for exactness, measurements should be made at these points in the original finished state of the cylinders.

APPENDIX B.

RECORD OF MEASUREMENTS OF TUBE CYLINDER.

I.—BORE OF TUBE.

(1) *Original interior.*

Distance from top.	Diameters.				
	No. 1.	No. 2.	No. 3.	No. 4.	Mean.
	Inches.	*Inches.*	*Inches.*	*Inches.*	*Inches.*
0.3 inch	9.499	9.499	9.4995	9.499	9.4991
2.12 inches	.499	.499	.4995	.4985	.499
3.95 inches	.499	.499	.499	.499	.499
5.77 inches	.499	.499	.499	.499	.499
7.6 inches	.4995	.4995	.4997	.4995	.4996
Mean	9.4991	9.4991	9.4993	9.499	9.4991

(2) *After assemblage of jacket.*

0.3 inch	9.4965	9.4965	9.4965	9.4965	9.4965
2.12 inches	.495	.4955	.4955	.4955	.4954
3.95 inches	.495	.495	.495	.495	.495
5.77 inches	.4945	.495	.495	.495	.4949
7.6 inches	.4955	.4955	.496	.4955	.4956
Mean	9.4953	9.4955	9.4956	9.4955	9.4955

(3) *After assemblage of A hoop.*

0.3 inch	9.491	9 4916	9.4915	9.4916	9.4914
2.12 inches	.4905	.4905	.4905	.4904	.4905
3.95 inches	.49	.49	.4902	.4898	.49
5.77 inches	.4902	.4903	.4902	.4902	.4902
7.6 inches	.4912	.4912	.4912	.4914	.4912
Mean	9.4906	9.4907	9.4907	9.4907	9.4907

(4) *After assemblage of B hoop.*

0.3 inch	9.4866	9.487	9.487	9.487	9.4869
2.12 inches	.4865	.4865	.486	.486	.4862
3.95 inches	.486	.486	.485	.4855	.4856
5.77 inches	.486	.4863	.4852	.4855	.4857
7.6 inches	.4865	.4868	.4868	.4865	.4866
Mean	9.4863	9.4865	9.486	9.4861	9.4862

(5) *After removal of B hoop.*

0.3 inch	9.4917	9.4913	9.4915	9.4913	9.4914
2.12 inches	.4908	.4904	.4907	.4903	.4905
3.95 inches	.49	.4897	.49	.4895	.4898
5.77 inches	.49	.4897	.49	.4898	.4899
7.6 inches	.4912	.4907	.4912	.491	.491
Mean	9.4907	9.4904	9.4907	9.4904	9.4905

(6) *After removal of A hoop.*

Distance from top.	Diameters. No. 1.	No. 2.	No. 3.	No. 4.	Mean.
	Inches.	*Inches.*	*Inches.*	*Inches.*	*Inches.*
0.3 inch	9.49[illegible]	9.4965	9.4963	9.4965	9.4964
2.12 inches	.495	.4955	.4953	.4953	.4953
3.95 inches	.4943	.495	.495	.495	.4948
5.77 inches	.4943	.495	.495	.495	.4948
7.6 inches	.496	.496	.496	.496	.496
Mean	9.4952	9.4956	9.4955	9.4956	9.4955

(7) *After removal of jacket (from half section).*

0.3 inch	9.5	9.4998	9.4998	9.4995	9.4998
2.12 inches	.498	.4978	.498	.4978	.4979
3.5 inches	.496	.496	.496	.496	.496
Mean	9.498	9.4979	9.4979	9.4978	9.4979

II.—EXTERIOR OF TUBE.

(1) *Original exterior.*

Distance from top.	Diameters. No. 1.	No. 2.	No. 3.	No. 4.	Mean.
	Inches.	*Inches.*	*Inches.*	*Inches.*	*Inches.*
0.3 inch	14.007	14.0057	14.0062	14.006	14.0062
2.12 inches	.0077	.006	.0062	.006	.0065
3.95 inches	.0075	.007	.007	.006	.0069
5.77 inches	.0077	.007	.0075	.0075	.0074
7.6 inches	.0075	.007	.0075	.007	.0072
Mean	14.0075	14.0065	14.0069	14.0065	14.0069

(2) *After removal of jacket (from half section).*

0.3 inch	14.0067	14.0067	14.0068	14.0065	14.0067
2.12 inches	.0062	.0062	.006	.006	.0061
3.5 inches	.0052	.0052	.0055	.0052	.0053
Mean	14.006	14.006	14.0061	14.0059	14.006

III.—LENGTH OF TUBE.

(1) *Original length.*

	Distance from edge.	Diameters. No. 1.	No. 2.	No. 3.	No. 4.	No. 5.	No. 6.	No. 7.	No. 8.	Mean
	Inch.	*Inches.*	*Inches*	*Inches*	*Inches.*	*Inches.*	*Inches.*	*Inches.*	*Inches.*	*Inches*
Outer	0.25	7.9025	7.9015	7.901	7.9005	7.9015	7.9025	7.9035	7.902	7.9019
Inner	0.25	.9035	.904	.902	.902	.902	9.035	.904	.9035	.9031
Mean		7.903	7.9028	7.9015	7.9012	7.9017	7.903	7.9037	7.9028	7.9025

(2) *After assemblage of jacket.*

	Distance from edge.	Diameters.								
		No. 1.	No. 2.	No. 3.	No. 4.	No. 5.	No. 6.	No. 7.	No. 8.	Mean.
	Inch.	*Inches.*	*Inches.*	*Inches.*	*Inches.*	*Inches.*	*Inches.*	*Inches.*	*Inches.*	*Inches.*
uter...........	0.25	7.904	7.9035	7.903	7.9025	7.902	7.903	7.904	7.9025	7.9031
nner...........	0.25	.9045	.904	.904	.904	.9025	.904	.905	.9045	.9041
Mean......	....	7.9042	7.9037	7.9033	7.9033	7.9023	7.9035	7.9045	7.9035	7.9036

(3) *After assemblage of A hoop.*

uter...........	0.25	7.905	7.904	7.9035	7.9035	7.905	7.9065	7.905	7.905	7.9047
nner...........	0.25	.9065	.9065	.906	.906	.907	.907	.9065	.9075	.9066
Mean......	......	7.9057	7.9053	7.9048	7.9048	7.906	7.9067	7.9057	7.9062	7.9057

(4) *After assemblage of B hoop.*

uter...........	0.25	7.907	7.906	7.9035	7.9045	7.904	7.9055	7.9065	7.907	7.9055
nner...........	0.25	.908	.9075	.9055	.9055	.907	.907	9.085	.9085	.9072
Mean......	......	7.9075	7.9067	7.9045	7.905	7.9055	7.9062	7.9075	7.9077	7.9063

(5) *After removal of B hoop.*

uter..........	0.25	7.903	7.902	7.901	7.902	7.902	7.903	7.904	7.9035	7.9026
nner..........	0.25	.905	.904	.9035	.903	.9035	.904	.905	.905	.9041
Mean	.....	7.904	7.903	7.9023	7.9025	7.9028	7.9035	7.9045	7.9042	7.9033

(6) *After removal of A hoop.*

uter.......	0.25	7.9035	7.903	7.902	7.9015	7.9025	7.903	7.904	7.904	7.9029
nner...........	0.25	.9047	.904	.903	.903	.9035	.9045	.905	.9055	.9041
Mean......	....	7.9041	7.9035	7.9025	7.9022	7.903	7.9038	7.9045	7.9047	7.9035

RECORD OF MEASUREMENTS OF JACKET CYLINDER.

IV.—INTERIOR OF JACKET.

(1) *Original interior.*

Distance from top.	Diameters.				
	No. 1.	No. 2.	No. 3.	No. 4.	Mean.
	Inches.	*Inches.*	*Inches.*	*Inches.*	*Inches.*
0.125 inch	14.001	14.0005	14.001	14.0005	14.0007
1.95 inches	.000	.000	.000	.000	.000
3.80 inches	.000	13.9995	.000	.000	.000
5.60 inches	.000	.9995	.000	.000	.000
7.435 inches	.0005	14.0005	.0005	.0005	.0005
Mean	14.0003	14.000	14.0003	14.0002	14.0002

(2) *After assemblage on tube (at ends).*

Distance from top.	Diameters.				
	No. 1.	No. 2.	No. 3.	No. 4.	Mean.
	Inches.	*Inches.*	*Inches.*	*Inches.*	*Inches.*
0. 125 inch	14. 005	14. 0045	14. 005	14. 005	14. 0049
7. 435 inches	. 005	. 0045	. 005	. 0045	. 0047
Mean	14. 005	14. 0045	14. 005	14. 0047	14. 0048

(3) *After assemblage of A hoop (at ends).*

0. 25 inch	14. 000	13. 9992	13. 9995	13. 9992	13. 9995
7. 435 inches	13. 9995	. 9995	. 9992	. 9992	. 9993
Mean	13. 9997	13. 9994	13. 9994	13. 9992	13. 9994

(4) *After assemblage of B hoop (at ends).*

0. 125 inch	13. 996	13. 996	13. 996	13. 996	13. 996
7. 435 inches	. 9965	. 9965	. 996	. 9958	. 9962
Mean	13. 9962	13. 9962	13. 996	13. 9959	13. 9961

(5) *After removal of B hoop (at ends).*

0. 125 inch	14. 000	14. 000	13. 995	13. 9995	13. 9997
7. 435 inches	. 000	. 000	. 9995	. 9995	. 9997
Mean	14. 000	14. 000	13. 9995	13. 9995	13. 9997

(6) *After removal of A hoop (at ends).*

0. 125 inch	14. 0042	14. 004	14. 004	14. 0045	14. 0042
7. 435 inches	. 005	. 005	. 0048	. 005	. 005
Mean	14. 0046	14. 0045	14. 0044	14. 0047	14. 0046

(7) *After removal of tube (from half section).*

4. 5 inches	13. 9975	13. 9973	13. 9983	13. 998	13. 9978
5 6 inches	. 999	. 999	. 9995	. 9995	. 9992
7. 3 inches	14. 0015	14. 0015	14. 0015	14. 0015	14. 0015
Mean	13. 9993	13. 9993	13. 9998	13. 9996	13. 9995

V.—EXTERIOR OF JACKET.

(1) *Original exterior.*

Distance from top.	Diameters.				
	No. 1.	No. 2.	No. 3.	No. 4.	Mean.
	Inches.	*Inches.*	*Inches.*	*Inches.*	*Inches.*
0. 125 inch	22. 105	22. 105	22. 1055	22. 106	22. 1054
1. 95 inches	. 105	. 105	. 105	. 106	. 1053
3. 80 inches	. 104	. 105	. 1055	. 1065	. 1053
5. 60 inches	. 106	. 1045	. 1055	1065	. 1056
7. 435 inches	. 106	. 105	. 1055	. 1065	. 1058
Mean	22. 1052	22. 1049	22. 1054	22. 1063	22. 1055

(2) *After assemblage on tube.*

Distance from top.	Diameters.				
	No. 1.	No. 2.	No. 3.	No. 4.	Mean.
0. 125 inch	22. 108	22. 108	22. 107	22. 1075	22. 1076
1. 95 inches	. 107	. 108	. 1075	. 1075	. 1075
3. 80 inches	. 1085	. 1085	. 1085	. 1085	. 1085
5. 60 inches	. 109	. 1085	. 1085	. 1085	. 1086
7. 435 inches	. 109	. 1085	. 1085	. 109	. 1088
Mean	22. 1083	22. 1083	22. 108	22. 1082	22. 1082

(3) *Prepared for shrinkage of A hoop.*

0. 125 inch	22. 0305	22. 03	22. 0295	22. 03	22. 03
1. 95 inches	. 03	. 029	. 0285	. 029	. 0291
3. 80 inches	. 03	. 029	. 029	. 029	. 0292
5. 60 inches	. 03	. 03	. 0295	. 0295	. 0297
7. 435 inches	. 03	. 029	. 0295	. 0295	. 0295
Mean	22. 0301	22. 0294	22. 0292	22. 0294	22. 0295

(4) *After removal of A hoop.*

0. 125 inch	22. 0307	22. 0305	22. 0305	22. 03	22. 0304
1. 95 inches	. 0305	. 0295	. 0295	. 0297	. 0295
3. 80 inches	. 0305	. 0295	. 0295	. 0295	. 0297
5. 60 inches	. 0507	. 03	. 03	. 03	. 0301
7. 435 inches	. 0305	. 0295	. 0295	. 0297	. 0298
Mean	22. 0306	22. 0298	22. 0298	22. 0298	22. 0300

(5) *After removal of tube (from half section).*

4. 5 inches	22. 0267	22. 0267	22. 0265	22. 0265	22. 0266
5. 6 inches	. 027	. 026	. 0265	. 027	. 0266
7. 435 inches	. 0278	. 0272	. 028	. 028	. 0277
Mean	22. 0272	22. 0266	22. 027	22. 0272	22. 0269

VI.—LENGTH OF JACKET.

(1) *Original length.*

	Distance from edge.	Diameters.								
		No. 1.	No. 2.	No. 3.	No. 4.	No. 5.	No. 6.	No. 7.	No. 8.	Mean.
	Inch.	*Inches.*	*Inches.*	*Inches.*	*Inches.*	*Inches.*	*Inches.*	*Inches.*	*Inches.*	*Inches.*
ter	0. 25	7. 551	7. 551	7. 554	7. 553	7. 5515	7. 551	7. 551	7. 5515	7. 5517
ier	0. 25	555	. 554	. 5565	. 555	. 554	. 555	. 555	. 554	. 5548
Mean		7. 553	7. 5525	7. 5553	7. 554	7. 5527	7. 553	7. 553	7. 5527	7. 5533

(2) *After assemblage on tube.*

er	0. 25	7. 551	7. 5507	7. 5535	7. 553	7. 553	7. 5515	7. 5505	7. 55	7. 5516
er	0. 25	. 554	. 5545	. 5555	. 5555	. 5555	. 554	. 554	. 5535	. 5546
Mean		7. 5525	7. 5526	7. 5545	7. 5542	7. 5542	7. 5527	7. 5522	7. 5517	7. 5531

(3) *After assemblage of A hoop.*

	Distance from edge.	Diameters.								
		No. 1.	No. 2.	No. 3.	No. 4.	No. 5.	No. 6.	No. 7.	No. 8.	Mean.
Outer	0.25	7.553	7.553	7.5535	7.554	7.553	7.5535	7.5525	7.552	7.5531
Inner	0.25	.556	.556	.557	.5565	.556	.5565	.5565	.556	.5563
Mean		7.5545	7.5545	7.5552	7.5553	7.5545	7.555	7.6545	7.5543	7.5547

(4) *After assemblage of B hoop.*

Outer	0.25	7.554	7.5535	7.554	7.5545	7.555	7.554	7.553	7.5535	7.5539
Inner	0.25	.5565	.557	.557	.558	.558	.558	.556	.5565	.5571
Mean		7.5552	7.5553	7.5555	7.5562	7,5565	7.556	7.5545	7.553	7.5555

(5) *After removal of B hoop.*

Outer	0.25	7.551	7.5505	7.5525	7.5525	7.553	7.552	7.551	7.551	7.5518
Inner	0.25	.554	.554	.5545	.5555	553	.555	.555	.554	.5548
Mean		7.5525	7.5522	7.5535	7.554	7.5545	7.5515	7.5535	7.5525	7.5533

(6) *After removal of A hoop.*

Outer	0.25	7.5505	7.551	7.553	7.5525	7.5525	7.552	7.551	7.551	7.5517
Inner	0.25	.553	.554	.555	.555	.5545	.5545	.554	.5535	.5542
Mean		7.5517	7.5525	7.554	7.5537	7.5535	7.5533	7.5525	7.5533	7.5529

RECORD OF MEASUREMENTS OF A HOOP.

VII.—INTERIOR OF A HOOP.

(1) *Original interior.*

Distance from top.	Diameters.				
	No. 1.	No. 2.	No. 3.	No. 4.	Mean.
	Inches.	*Inches.*	*Inches.*	*Inches.*	*Inches.*
0.1 inch	21.998	21.9975	21.9975	21.998	21.9977
1.92 inches	.997	.9965	.997	.997	.9969
3.75 inches	.9985	.998	.9985	.9985	.9984
5.57 inches	.997	.9968	.997	.997	.9969
7.40 inches	.998	.997	.9975	.9975	.9975
Mean	21.9977	21.9972	21.9975	21.9976	21.9975

(2) *After assemblage on jacket and tube (at ends).*

0.1 inch	22.026	22.0257	22.0258	22.0257	22.0258
7.40 inches	.025	.025	.025	.025	.025
Mean	22.0255	22.0254	22.0254	22.0254	22.0254

(3) *After assemblage of B hoop (at ends).*

Distance from top.	Diameters.				
	No. 1.	No. 2.	No. 3.	No. 4.	Mean.
	Inches.	*Inches.*	*Inches.*	*Inches.*	*Inches.*
0.1 inch	22.0215	22.0217	22.0217	22.0215	22.0216
7.40 inches	.022	.0215	.0215	.0215	.0216
Mean	22.0217	22.0216	22.0216	22.0215	22.0216

(4) *After removal of B hoop (at ends).*

0.1 inch	22.026	22.026	22.0255	22.026	22.0259
7.40 inches	.026	.025	.026	.0255	.0256
Mean	22.026	22.0255	22.0257	22.0257	22.0257

(5) *After being removed from the section. Cut open on one side.*

0.1 inch	21.9972	21.9962	21.9975	21.998	21.9972
3.75 inches	.9977	.9962	.9975	.999	.9976
7.40 inches	.9975	.996	.9975	.9985	.9974
Mean	21.9976	21.9961	21.9975	21.9985	21.9974

VIII.—EXTERIOR OF A HOOP.

(1) *Original exterior.*

Distance from top.	Diameters.				
	No. 1.	No. 2.	No. 3.	No. 4.	Mean.
	Inches.	*Inches.*	*Inches.*	*Inches.*	*Inches.*
0.1 inch	26.427	26.4265	26.4265	26.4265	26.4266
1.92 inches	.4315	.432	.432	.4325	.432
3.75 inches	.432	.432	.432	.4325	.4321
5.57 inches	.4325	.432	.4325	.433	.4325
7.40 inches	.432	.432	.4325	.433	.4324
Mean	26.431	26.4309	26.4311	26.4315	26.4311

(2) *After assemblage on jacket and tube.*

0.1 inch	26.4545	26.4525	26.453	26.4545	26.4536
1.92 inches	.4565	.456	.4565	.4565	.4564
3.75 inches	.4565	.456	.4565	.4565	.4564
5.57 inches	.457	.4575	.4565	.457	.457
7.40 inches	.457	.457	.457	.457	.457
Mean	26.4563	26.4558	26.4559	26.4563	26.4561

(3) *Prepared for shrinkage of B hoop.*

0.1 inch	26.3335	26.334	26.334	26.334	26.3339
1.92 inches	.3342	.335	.335	.335	.3348
3.75 inches	.3355	.335	.335	.335	.3351
5.57 inches	.3355	.3355	.336	.435	.3355
7.40 inches	.3355	.3355	.336	.335	.3355
Mean	26.3348	26.335	26.3352	26.3348	26.3350

(4) *After removal of B hoop.*

Distance from top.	Diameters.				
	No. 1.	No. 2.	No. 3.	No. 4.	Mean.
0. 1 inch	26. 3345	26. 3345	26. 3335	26. 3335	26. 334
1. 92 inches	. 3338	. 3342	. 3338	. 3338	. 3339
3. 75 inches	. 3343	. 335	. 334	. 3348	. 3345
5. 57 inches	. 335	. 3352	. 335	. 334	. 3348
7. 40 inches	. 335	. 335	. 3345	. 3343	. 3347
Mean	26. 3345	26. 3348	26. 3342	26. 3341	26. 3344

IX.—LENGTHS OF A HOOP.

(1) *Original length.*

	Distance from edge.	Diameters.								
		No. 1.	No. 2.	No. 3.	No. 4.	No. 5.	No. 6.	No. 7.	No. 8.	Mean.
	Inch.	*Inches.*	*Inches.*	*Inches.*	*Inches.*	*Inches*	*Inches.*	*Inches.*	*Inches.*	*Inches.*
Outer	0. 25	7. 499	7. 4985	7. 499	7. 4995	7. 5005	7. 500	7. 4995	7. 4995	7. 4994
Inner	0. 25	. 498	. 4975	. 4995	500	. 501	500	. 500	. 4995	. 4994
Mean		7. 4985	7. 498	7. 4992	7. 4998	7. 5007	7. 500	7. 4998	7. 4995	7. 4994

(2) *After assemblage on jacket and tube.*

Outer	0. 25	7. 498	7. 498	7. 499	7. 499	7. 499	7. 4985	7. 4975	7. 4975	7. 4983
Inner	0. 25	. 498	. 499	. 499	. 500	. 500	. 4995	. 499	. 4985	. 4991
Mean		7. 498	7. 4985	7. 499	7. 4995	7. 4995	7. 499	7. 4982	7. 498	7. 4987

(3) *After assemblage of B hoop.*

Outer	0. 25	7. 499	7. 4985	7. 499	7. 499	7. 499	7. 4995	7. 499	7. 498	7. 4989
Inner	0. 25	. 499	. 500	. 500	. 500	. 500	. 500	. 500	. 499	. 4997
Mean		7. 499	7. 992	7. 4995	7. 4995	7. 4995	7. 4998	7. 4995	7. 4985	7. 4993

(4) *After removal of B hoop.*

Outer	0. 25	7. 4965	7. 4962	7. 4967	7. 4968	7. 498	7. 4972	7. 497	7. 4957	7. 4968
Inner	0. 25	. 497	. 497	. 4969	. 499	. 4988	. 498	. 498	. 4963	. 4976
Mean		7. 4967	7. 4966	7. 4968	7. 4979	7. 4984	7. 4976	7. 4975	7. 496	7. 4972

(5) *After being removed from the section, cut open on one side.*

Outer	0. 25	7. 499	7. 499	7. 499	7. 5005	7. 501	7. 500	7. 4995	7. 4987	7. 4996
Inner	0. 25	. 499	. 499	. 499	. 501	. 5015	. 500	. 4995	. 4985	. 4997
Mean		7. 499	7. 499	7. 499	7. 5007	7. 5012	7. 500	7. 4995	7. 4986	7. 4996

RECORD OF MEASUREMENTS OF B HOOP.

X.—Interior of B hoop.

(1) *Original interior.*

Distance from top.	Diameters.				
	No. 1.	No. 2.	No. 3.	No. 4.	Mean.
	Inches.	*Inches.*	*Inches.*	*Inches.*	*Inches.*
0. 1 inch	26. 299	26. 2975	26. 298	26. 2995	26. 2985
1. 92 inches	. 2995	. 298	. 298	. 2995	. 2987
3. 75 inches	. 300	. 299	. 300	. 300	. 2998
5. 57 inches	. 2995	. 2985	. 2995	. 299	. 2991
7. 40 inches	. 300	. 299	. 300	. 300	. 2997
Mean	26 2996	26. 2984	26. 2991	26. 2996	26. 2992

(2) *After assemblage on A hoop, jacket, and tube (at ends).*

0. 1 inch	26. 3285	26. 329	26. 329	26. 3285	26. 3288
7. 40 inches	. 33	. 3295	. 33	. 329	. 3296
Mean	26. 3292	26. 3293	26. 3295	26. 3287	26. 3292

(3) *After being removed from the section, cut open on one side.*

0. 1 inch	26. 3015	26. 301	26. 3002	26. 3002	26. 3007
3. 75 inches	. 302	. 3025	. 3015	. 3002	. 3015
7. 40 inches	. 301	. 3023	. 301	. 300	. 3011
Mean	26. 3015	26 3019	26. 3009	26. 3001	26. 3011

XI.—Exterior of B hoop.

(1) *Original exterior (at ends).*

Distance from top.	Diameters.				
	No. 1.	No. 2.	No. 3.	No. 4.	Mean.
	Inches.	*Inches.*	*Inches.*	*Inches.*	*Inches.*
0. 1 inch.	31. 4985	31. 4975	31. 498	31. 498	31. 498
7. 40 inches	. 498	. 4985	. 498	. 4985	. 4982
Mean	31. 4982	31. 498	31. 498	31. 4982	31. 4981

(2) *After assemblage (at ends).*

0. 1 inch	31. 525	31. 5255	31. 525	31 5249	31. 5251
7. 40 inches	. 526	. 527	. 526	. 526	. 5262
Mean ..	31. 5255	31. 5262	31. 5255	31. 5254	31. 5257

XII.—LENGTHS OF HOOP.

(1) *Original length.*

	Distance from edge.	Diameters.								
		No. 1.	No. 2.	No. 3.	No. 4.	No. 5.	No. 6.	No. 7.	No. 8.	Mean.
	Inch.	*Inches.*	*Inches.*	*Inches.*	*Inches.*	*Inches.*	*Inches.*	*Inches.*	*Inches.*	*Inches.*
Outer..........	0.25	7.4965	7.4965	7.4965	7.4968	7.496	7.495	7.4935	7.496	7.4958
Inner..........	0.25	.495	.495	.4955	.495	.495	.494	.4925	.4935	.4944
Mean....	...	7.4957	7.4957	7.496	7.4959	7.4955	7.4945	7.493	7.4947	7.4951

(2) *After assemblage on A hoop, jacket, and tube.*

	Distance from edge.	No. 1.	No. 2.	No. 3.	No. 4.	No. 5.	No. 6.	No. 7.	No. 8.	Mean.
Outer...........	0.25	7.496	7.4965	7.495	7.4955	7.494	7.493	7.492	7.493	7.4944
Inner...........	0.25	.494	.495	.4935	.494	.4925	.492	.4905	.492	.4929
Mean.............		7.495	7.4957	7.4943	7.4947	7.4933	7.4925	7.4912	7.4925	7.4937

(3) *After removal from the section, cut open on one side.*

	Distance from edge.	No. 1.	No. 2.	No. 3.	No. 4.	No. 5.	No. 6.	No. 7.	No. 8.	Mean.
Outer... ...	0.25	7.496	7.497	7.497	7.497	7.4957	7.4945	7.494	7.4945	7.4957
Inner...........	0.25	.494	.495	.4945	.4945	.4945	.493	.4925	.494	.494
Mean....	.....	7.495	7.496	7.4957	7.4957	7.4951	7.4937	7.4933	7.4942	7.4949

APPENDIX C.

VARIATIONS OF PRESSURES AND CHANGES FROM ORIGINAL DIMENSIONS OF CYLINDERS IN THE SEVERAL STAGES OF CONSTRUCTION.

[Computed from the actual shrinkages employed, viz, $\phi_1 = .0004786$; $\phi_2 = .0014547$; $\phi_3 = .0013812$.]

First stage.—Assemblage of jacket on tube.

The value of φ_1 is expressed by the following, from formula (12), Notes on the Construction of Ordnance, No. 31:

$$\varphi_1 = \frac{(4R_0^2 + R_1^2)P_1 - p_1}{3(R_1^2 - R_0^2)E_0} + \frac{(4R_2^2 + R_1^2)P_1 + p_1}{3(R_2^2 - R_1^2)E_1} \quad . \quad . \quad . \quad . \quad (12)a.$$

Replacing the first term by its logarithm and reducing the known quantities in the second member, expressing them as logarithmic coefficients of $P_1 + p_1$ we have:

$$^*[6.6799406] = [6.1429152]\,P_1 - p_1 + [6.2306380]\,P_1 + p_1 \quad . \quad . \quad . \quad (12)b.$$

From which

$$P_1 + p_1 = 1.549 \text{ tons}$$

Substituting this value in (12)*a* above and reducing we obtain:

$$\varphi_1 = .0004786 = .0002152 + .0002634$$

which being interpreted gives:

Relative tangential contraction of exterior of tube = 0.2152 thousandths.

Relative tangential extension of interior of jacket = 0.2634 thousandths.

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* The bracketed figures throughout the text represent the logarithms of corresponding numbers.

To obtain the tangential contraction of the bore of the tube and extension of the exterior of the jacket the formulas are, respectively:

$$\frac{\Delta R_0}{\ }=\frac{5\,R_1^2\,\overline{P_1+p_1}}{3\,(R_1^2-R_0^2)\,E_0}\quad\text{and}\quad\frac{\Delta R^2}{R_2}=\frac{5\,R_1^2\,\overline{P_1+p_1}}{3\,(R_2^2-R_1^2)\,E_1}$$

Whence by substitution and reduction we obtain:
Relative tangential contraction of bore of tube = 0.3786.
Relative tangential extension of exterior of jacket = 0.1211.
To find the variations in length the formulas* are:

For the tube:

$$\frac{d\,\Delta h_0}{dh_0}=-\frac{R_1^2\,\overline{P_1+p_1}}{3\,(R_1^2-R_0^2)\,E_0}=\quad 0.0757 \text{ thousandths per linear unit.}$$

For the jacket:

$$\frac{d\,\Delta h_1}{dh_1}=\frac{R_1^2\,\overline{P_1+p_1}}{3\,(R_2^2-R_1^2)\,E_1}=+\,0.0242 \text{ thousandths per linear unit.}$$

Second stage.—Assemblage of A hoop on tube and jacket.
The value of φ_2 is expressed by formula (13) modified, as follows:

$$\phi_2=\frac{5\,R_1^2\,p_1+(4\,R_1^2+R_2^2)\,\overline{P_2+p_2}}{3\,(R_2^2-R_1^2)\,E_1}+\frac{(4\,R_3^2+R_2^2)\,\overline{P_2+p_2}}{3\,(R_3^2-R_2^2)\,E^2}\quad\ldots\quad(13)a.$$

in which

$$p_1=-\frac{5\,R_2^2\,(R_1^2-R_0^2)\,E_0\,\overline{P_2+p_2}}{E_0\,(R_1^2-R_0^2)\,(4\,R_2^2+R_1^2)+E_1\,(R_2^2-R_1^2)\,(4\,R_0^2+R_1^2)}$$

or, by reduction,

$$p_1=-[9.7956479]\,\overline{P_2+p_2}\quad\ldots\ldots\ldots\quad(13)b.$$

We have

$$\phi_2=.0014547\ [7.1627767]$$

Substituting this, together with the value of p_1, in (13)*a*, and reducing the second member, we obtain

$$[7.1627767]=[5.7186408]\,\overline{P_2+p_2}+(6.5625461)\,\overline{P_2+p_2}\quad\ldots\ldots\quad(13)c.$$

whence

$$\overline{P_2+p_2}=3.484 \text{ tons}$$

This substituted in (13)*c*, replacing ϕ_2 for its logarithm, gives

$$\phi_2=.0014547=.0001823+.0012725$$

whence

Relative tangential contraction of exterior of jacket =0.1823 thousandths.
Relative tangential extension of interior A loop =1.2725 thousandths.

Returning now to the inner contact surface the value of $\overline{P_2+p_2}=3.484$ substituted in (13)*b* gives

$$p_1=-2.1764 \text{ tons}$$

This value represents the variation or relief of pressure that would take place at this inner contact surface if the pressure $\overline{P_2+p_2}$ were supposed removed from the exterior of the jacket. Conversely, then, it stands for the increase of pressure at the said surface due to the assemblage of the A hoop, since that assemblage produces the given pressure $\overline{P_2+p_2}$. Therefore, changing the sign of p_1 and adding to the pressure previously existing, we have

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*Taken from pp. 12 and 8, Notes on Construction of Ordnance, No. 6.

$$\overline{P_1+p_1}=\overline{P}_1+p_1+p_1=1.549+2.1764=3.7254 \text{ tons}$$

to represent the pressure at the inner contact surface; whilst at the outer contact surface we have $\overline{P_2+p_2}=3.484$ tons.

From formula (12) the value of ϕ_1 is now expressed as follows:

$$\phi_1=\frac{(4\,R_0^2+R_1^2)\,\overline{P_1+p_1}}{3\,(R_1^2-R_0^2)\,E_0}+\frac{(4\,R_2^2+R_1^2)\,\overline{P_1+p_1}-5\,R_2^2\,\overline{P_2+p_2}}{3\,(R_2^2-R_1^2)\,E_1}$$

Substituting the given values and reducing the two terms composing the second member we obtain

$$\phi_1=.0004786=.0005177-.00039.$$

Then

Relative tangential contraction of exterior of tube=0.5177 thousandths.
Relative tangential extension of interior of jacket=−0.039 thousandths.

The tangential compression of the bore of the tube is given by

$$\frac{\Delta R_0}{R_0}=\frac{5\,R_1^2\,\overline{P_1+p_1}}{3\,(R_1^2-R_0^2)\,E_0}=0.911 \text{ thousandths per linear unit;}$$

and the tangential extension of the exterior of the A hoop, by

$$\frac{\Delta R_3}{R_3}=\frac{5\,R_2^2\,\overline{P_2+p_2}}{3\,(R_3^2-R_2^2)\,E_2}=0.9472 \text{ thousandths per linear unit.}$$

The variations in length are derived from the following:

$$\frac{d\Delta h_0}{dh_0}=-\frac{R_1^2\,\overline{P_1+p_1}}{3\,(R_1^2-R_0^2)\,E_0}=-0.1822 \text{ thousandths per linear unit.}$$

$$^*\frac{d\Delta h_1}{dh_1}=\frac{R_1^2\,\overline{P_1+p_1}-R_2^2\,\overline{P_2+p_2}}{3\,(R_2^2-R_1^2)\,E_0}=-0.0763 \text{ thousandths per linear unit.}$$

$$\frac{d\Delta h_2}{dh_2}=\frac{R_2^2\,\overline{P_2+p_2}}{3\,(R_3^2-R_2^2)\,E_2}=+0.1895 \text{ thousandths per linear unit.}$$

Third (or final) stage.—Assemblage of B hoop on tube, jacket, and A hoop. [This solution is not given in Note 31, but is a direct sequence of the methods given.] We have the given shrinkage:

$$\phi_1=.0013612\ [7.1339405]$$

To adapt formula (14) to the case, we must place

$$p_3=-(P_3+p_3) \text{ and substitute } (P_3+p_3) \text{ for } P_3$$

whence formula (14):

$$\phi_3=\frac{5\,R_2^2\,p_2+(4\,R_2^2+R_3^2)\,(P_3+p_3)}{3\,(R_3^2-R_2^2)\,E_2}+\frac{(4\,R_4^2+R_3^2)\,(P_3+p_3)}{3\,(R_4^2-R_3^2)\,E_3}\quad . . . \quad (14)a.$$

The unknown quantities in this equation are p_2 and (P_3+p_3), but we may express the former in terms of the latter, and thence obtain the value of (P_3+p_3), which represents the pressure, at the outer contact surface of the structure, induced by the assemblage of the outer (B) hoop.

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*Taken from page 14, Notes on Construction of Ordnance, No. 6.

To express the value of p_2 in terms of (P_3+p_3) we have from the general equations of equilibrium concerned (see example p. 17, Notes on the Construction of Ordnance, No. 7) upon substituting therein

$$p_3=-(P_3+p_3);\ \text{and } p_0=0, \text{ since } P_0=0$$

the following:

$$p_1=\frac{5\ R_2^2\ (R_1^2-R_0^2)\ E_0}{E_0(R_1^2-R_0^2)\ (4\ R_2^2+R_1^2)+E_1\ (R_2^2-R_1^2)\ (4\ R_0^2+R_1^2)}\,p_2$$

and

$$p_2=-\frac{5\ R_3^2\ (R_2^2-R_1^2)\ E_1\ (P_3+p_3)}{E_1\ (R_2^2-R_1^2)\ (4\ R_3^2+R_2^2)+E_2\ (R_3^2-R_2^2)\ (4R_1^2+R_2^2)-5\ R_1^2\times c^1]}$$

in the latter, of which c^1 represents the fractional coefficient of p_2 in the first.

By substituting the values of the known quantities and reducing, these two equations become

$$p_1=\ [9.7956479]\ p_2 \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (14)b$$
$$p_2=-[9.9687559]\ P_3+p_3) \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (14)c$$

Substituting this latter in equation (14)*a*, also the logarithm of ϕ_3 and reducing the second member, we obtain

$$[7.1339405]=[5.6253724]\ (P_3+p_3)+[6.5584958]\ (P_3+p_3) \quad . \quad . \quad . \quad . \quad (14)d.$$

whence,

$$(P_3+p_3)=3.3692 \text{ tons.}$$

This substituted in (14)*d*, replacing ϕ_3 for the first member, gives

$$\phi_3=.0001422+001219=.0013612.$$

whence,

Relative tangential contraction of exterior of A hoop = 0.1422 thousandths.

Relative tangential extension of interior of B hoop = 1.219 thousandths.

Passing now to the intermediate contact surface, where the shrinkage $\phi_2=.0014547$ has been applied, we wish to find the increase of pressure brought about by the assemblage of the B hoop.

If the pressure (P_3+p_3) were supposed removed, the relief of the pressure at this surface would be given by the value of p_2, equation (14)*c*, when we substitute therein the given value of (P_3+p_3); conversely this value for p_2 may be taken to represent the increase we are seeking. Therefore, to obtain the pressure existing in this final stage at this contact surface, we have simply to find the indicated value of p_2, change its sign, and add to the pressure previously existing.

Substituting the value $(P_3+p_3)=3.3692$ in (14)*c* we obtain

$$p_2=-3.1353;$$

whence

$$(P_2+p_2)=\overline{P_2+p_2}+p_2=3.484+3.1353=6.6193 \text{ tons,}$$

which represents the pressure at the intermediate contact surface.

Resuming equation (13), we make the following substitutions:

$$p_2=-(P_2+p_2) \qquad P_2=(P_2+p_2) \qquad P_3=(P_3+p_3)$$

whence

$$\phi_2=\frac{+\qquad {}_1^2+R_2^2)\ (P_2+p_2)}{3\ (R_2^2-R_1^2)\ E_1}+\frac{(4\ R_3^2+R_2^2)\ (P_2+p_2)-5\ R_3^2\ (P_3+p_3)}{3\ (R_3^2-R_2^2)\ E_2}$$

The value of p_1 will be derived from equation (13)*b* by substituting therein the present value of (P_2+p_2). We thus obtain

$$p_1=-4.13485 \text{ tons.}$$

With the known value substituted in the second member of the expression for φ_3 above we find

$$\varphi_3 = .00034363 + .0011083 = .0014546$$

whence

Relative tangential contraction of exterior of jacket = 0.3463 thousandths.
Relative tangential extension of interior of A hoop = 1.1083 thousandths.

We pass now to the inner contact surface, where the shrinkage $\phi_1 = .0004786$ has been applied. The pressure existing at this surface in this final stage may be derived in either one of two ways. Technically it will be more correct to make the supposition that all pressure is removed from the exterior of the jacket; find the variation (relief) of pressure thereby induced at the contact surface between the jacket and tube; change the sign of this variation, and add to the value of $P_1 + p_1$, as found when these two cylinders were originally assembled alone. We have found the value of this variation in the value of p_1 above, viz:

$$p_1 = -4.13485 \text{ tons};$$

whence

$$(P_1 + p_1) = \overline{P_1 + p_1} + p_1 = 1.549 + 4.13485 = 5.68385 \text{ tons},$$

which represents the pressure at the inner contact surface for this final stage.

In another and equally direct way we may find the value sought by considering the assemblage of the outer (B) hoop alone, find the variation (relief) of pressure which would be induced at the inner contact surface by supposing this hoop removed from the structure, change its sign, and add to the pressure existing at that surface in the *second* stage of the construction.

The variation of pressure now sought will be derived from equation (14)*b* by substituting therein the value

$$p_3 = -3.1353 \text{ tons}$$

already found by the solution of equation (14)*c*; whence we obtain

$$p_1 = -1.9585 \text{ tons}.$$

Then, from what proceeds

$$(P_1 + p_1) = \overline{P_1} + \overline{p_1} + p_1 = 3.7254 + 1.9585 = 5.6839 \text{ tons},$$

or the same value, as previously found.

Resuming equation (12) we make the following substitutions:

$$p_0 = 0, \text{ since } P_0 = 0; \text{ and } p_1 = -(P_1 + p_1),\ P_2 = (P_2 + p_2),$$

whence

$$\varphi_1 = \frac{(4\,R_0^2 + R_1^2)\,(P_1 + p_1)}{3\,(R_1^2 - R_0^2)\,E_0} + \frac{(4\,R_2^2 + R_1^2)\,(P_1 + p_1) - 5\,R_2^2\,(P_2 + p_2)}{3\,(R_2^2 - R_1^2)\,E_1}$$

and substituting the given values,

$$\phi' = .0007899 - .0003112 = .0004787$$

whence

Relative tangential contraction of exterior of tube = 0.7899 thousandths.
Relative tangential extension of interior of jacket = −0.3112 thousandths.

Resuming the values found for the pressures existing at the several contact surfaces in this final stage of the construction, we have

$$(P_1 + p_1) = 5.6839,\ (P_2 + p_2) = 6.6193, \text{ and } (P_3 + p_3) = 3.3692 \text{ tons}.$$

The tangential compression of the bore of tube is then derived from:

$$\frac{\Delta R_0}{R_0} = \frac{5\,R_1^2(P_1 + p_1)}{3\,(R_1^2 - R_0^2)\,E_0} = 1.39 \text{ thousandths per linear unit}.$$

and the tangential extension of the exterior of the structure, that is, of the B hoop, from:

$$\frac{\Delta R_4}{R_4} = \frac{5 R_3^2 (P_3 + p_3)}{3 (R_4^2 - R_3^2) E_3} = 0.9046 \text{ thousandths per linear unit.}$$

The variations in length are derived from the following:

$$\frac{d \Delta h_0}{dh_0} = - \frac{R_1^2 (P_1 + p_1)}{3 (R_1^2 - R_0^2) E_0} = - 0.278 \text{ thousandths per linear unit.}$$

$$\frac{d \Delta h_1}{dh_1} = \frac{R_1^2 (P_1 + p_1) - R_2^2 (P_2 + p_2)}{3 (R_2^2 - R_1^2) E_1} = - 0.1667 \text{ thousandths per linear unit.}$$

$$\frac{d \Delta h_2}{dh_2} = \frac{R_2^2 (P_2 + p_2) - R_3^2 (P_3 + p_3)}{3 (R_3^2 - R_2^2) E_2} = + 0.0981 \text{ thousandths per linear unit.}$$

$$\frac{d \Delta h_3}{dh_3} = \frac{R_3^2 (P_3 + p_3)}{3 (R_4^2 - R_3^2) E_3} = + 0.18092 \text{ thousandths per linear unit.}$$

NOTE.—The preceding relative values are given in column (*b*), Table VIII, under "thousandths per linear unit," except that, in order to make the comparisons with the actual measurements direct, the following corrections for tangential extension of exterior of jacket and A hoop, due to their first assemblage, are made:

Second stage:

Exterior of jacket = — 0.1823 + 0.1211 = — 0.0612 thousandths per linear unit.

Third stage:

Exterior of jacket = — 0.3463 + 0.1211 = — 0.2252 thousandths per linear unit.

Exterior A-hoop = + 0.9472 — 0.1422 = + 0 8050 thousandths per linear unit.

The column (*b*), under inches, consists of the products obtained by multiplying the relative values of the changes by the corresponding interior diameters or lengths.

PLATE I.

POSITION OF TEST-SPECIMENS

Fig. 1.

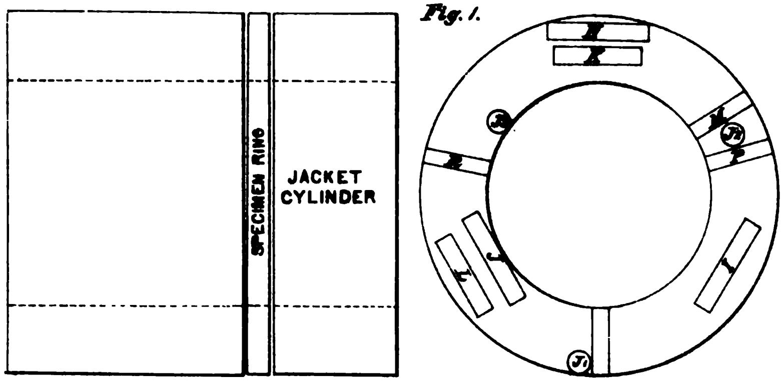


Fig. 3.

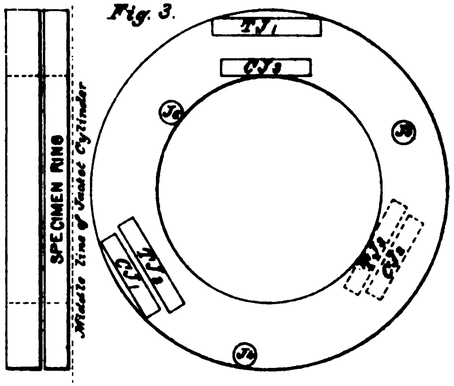


Fig. 2.

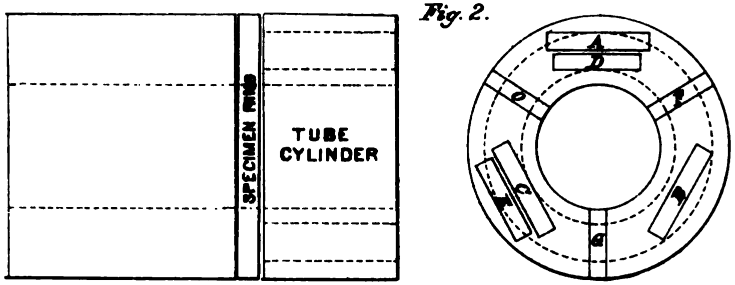
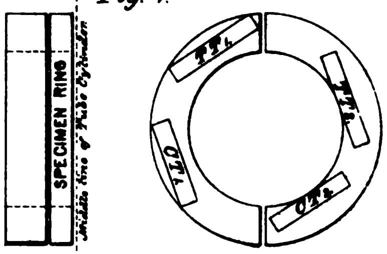


Fig. 4.



Appendix 27—1885.

H Ex1 pt2 v3 49 1

POSITION OF TEST - SPECIMENS

Fig. 1.

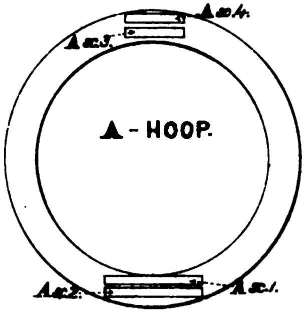


Fig. 2.

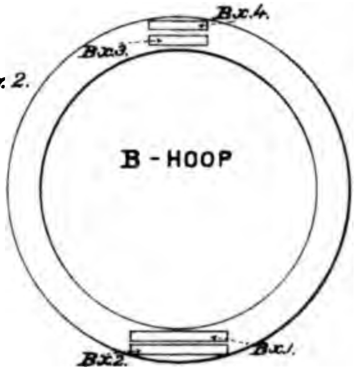


Fig. 3.

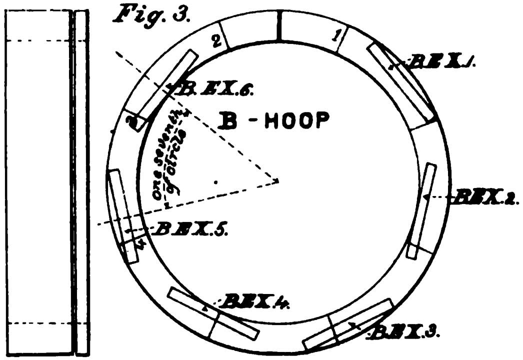
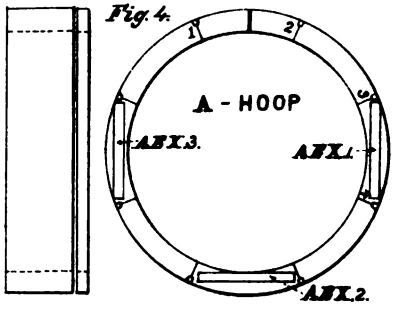


Fig. 4.

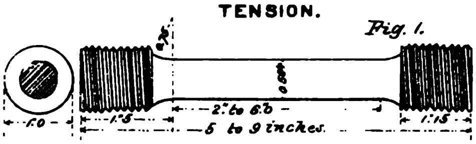


H Ex1 pt2 v3 49 1

DIMENSIONS OF TEST-SPECIMENS

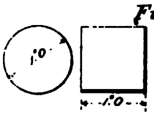
TENSION.

Fig. 1.



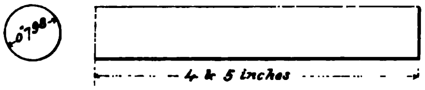
HARDNESS.

Fig. 2.



COMPRESSION.

Fig. 3.



FORM OF COMPRESSION SPECIMEN AFTER TEST.

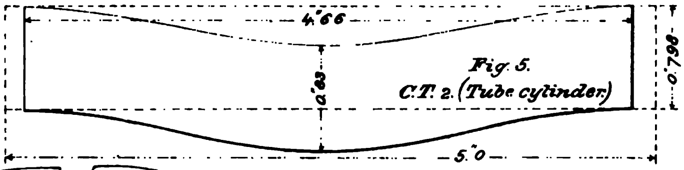


Fig. 5.
C.T. 2. (Tube cylinder)

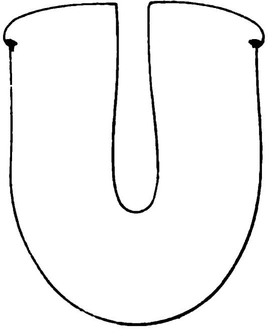


Fig. 6.
C.J.1. (Jacket cylinder)

Appendix 27—1885.

H Exl pt2 v3 49 1

PLATE IV.

SECTIONAL AND END VIEWS OF GUN-SECTION, ASSEMBLED.

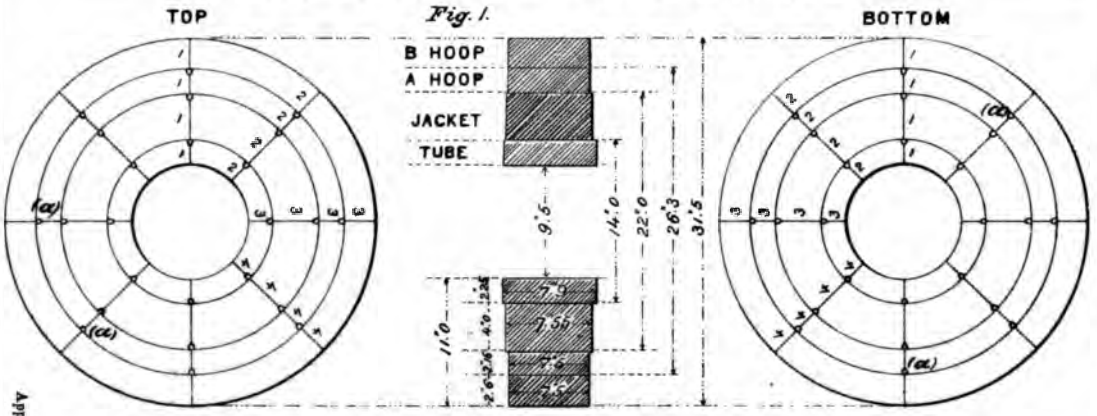


Fig. 1.

FORM OF CUT

Natural.

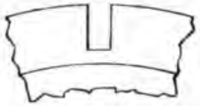


Fig. 2.

Anticipated.

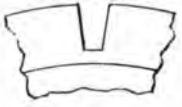


Fig. 3.

Actual.

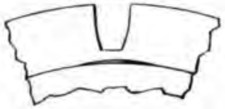


Fig. 4.

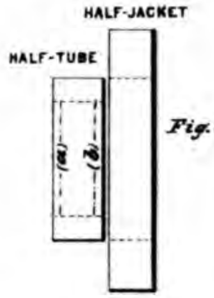


Fig. 5

Appendix 27—1885.

H Exl pt2 v3 49 1

APPENDIX 28.

REPORT ON EXPERIMENTAL CYLINDER, FROM THE 12-INCH CAST-IRON BREECH-LOADING RIFLE, HOOPED AND TUBED WITH STEEL.

By Capt. D. A. Lyle, Ordnance Department.

COMPOSITION.

The experimental cylinder for the 12-inch cast-iron breech-loading rifle, hooped and tubed with steel, is a compound or built-up cylinder, composed of four parts, viz: (1) The tube section (Whitworth steel); (2) the body (cast iron); (3) the A-hoop (Midvale steel); (4) the B-hoop (Midvale steel).

MATERIALS.

THE TUBE SECTION.

This was cut from the front end of the tube. An annular slice for test specimens, 1''.2 in thickness, was removed from between the section and the tube proper.

The end of the tube section toward the main body of the tube was marked "face." The tube was made by Sir Joseph Whitworth & Co. from "fluid-compressed steel."

THE CAST-IRON BODY.

The body for the experimental cylinder was taken from the breech end of the gun-casting, and about five inches in rear of the face of the breech of the finished gun. The initial tension-ring for breech-test specimens was taken out between the experimental cylinder and the breech of the gun. That end of the body of the cylinder which was next to the gun is called the "face," and is so marked and designated throughout the experiments.

THE HOOPS.

These were made from Midvale open-hearth steel, and were marked, respectively, "A_x" and "B_x."

The tube and hoops were rough-finished to within about one-eighth of an inch of their finished dimensions.

CONTRACT SPECIFICATIONS.

The cast-iron body of the experimental cylinder was provided for in the contract with the South Boston Iron Works, dated September 24, 1883, as follows:

"The casting [for the 12-inch hooped and tubed gun] shall be eighteen

(18) inches longer at the breech end than is called for on the attached drawing, to provide for a cylinder to be taken from that end for experimental purposes."

Again, the contract of June 30, 1884, provides "that before finish turning and boring the parts of the gun, an experimental cylinder, about ten inches long, representing a section of the gun over the chamber, will be assembled exactly as the gun is to be assembled, with the prescribed shrinkage and the same allowed variations. This experimental cylinder will also be unhooped, the several parts being successively removed by pouring molten metal about the exterior * * *." "All dimensions to be subject to such slight changes * * * as the Ordnance Department may deem necessary or advisable to make as the work progresses."

Allowed variations.

	Contract of June 30, 1884.	Instructions of Chief of Ordnance, April 22, 1885, and printed circular of December 1, 1884.
Boring the tube, limits	+".003 − 000	±".002
Turning of other parts Boring of other parts	±".003	±".003
Exterior diameters of three inner cylinders, limits		+".000 −".002
Parallelism of ends	.003	.0005
Eccentricity	.003	.002
Conicalness	.003	.002
Lengths		±".01

Surplus metal left for finishing exterior diameters of cast-iron body and A-hoop, after shrinking on and measuring exterior, +".08.

Exterior of B-hoop to be turned to finished dimensions at once.

INSTRUCTIONS.

In addition to the contract specifications, special instructions in regard to assembling and dismantling the experimental cylinder were given by the Chief of Ordnance United States Army, as follows:

ORDNANCE OFFICE, WAR DEPARTMENT,
Washington, D. C., April 22, 1885.

Capt. D. A. LYLE,
South Boston, Mass.:

SIR: In hooping the experimental cylinder provided for under the contract for the 12 inch B. L. rifle, cast iron, hooped and tubed with steel, the general instructions contained in the inclosed circular* relative to the assembling and dismantling of an experimental cylinder for the 8-inch B. L. rifle will be followed as far as practicable, except so far as modified herein. The following data and special instructions are also furnished you.

Dimensions of cylinders for the assemblage.

Measurements.	Tube.	Casting.	A-hoop.	B-hoop.
	Inches.	*Inches.*	*Inches.*	*Inches.*
Interior diameter	13.5	20.0	30.2	*45.0
Exterior diameter†				
Lengths	9.5	9.5	9.0	9.0

*As nearly as the size of this hoop will permit.

†As little surplus metal as practicable, beyond what is required for the shrinkage and finishing out for same, should be left on exterior diameter.

---

* See printed: "General Instructions for Assembling and Dismantling an Experimental Compound-Cylinder 8-inch B. L. Steel Rifle (Double Hooped)."

The values of the shrinkages to be applied are as follows:

Shrinkages.		Casting.		A hoop.		B hoop.	
		Thousandths per linear unit.	Inches.	Thousandths per linear unit.	Inches.	Thousandths per linear unit.	Inches.
Theoretical		0. 240	.0048	1. 750	0. 0686	1. 611	0. 0739
Prescribed limits	maximum	0. 290	.0058	1. 788	0. 0691	1. 644	0. 0754
	minimum	0. 190	.0038	1. 711	0. 0671	1. 578	0. 0724

The grooves for measuring the interior of the B hoop—see inclosed instructions—will be made before the hoop is in place.

In making the measurements on this compound cylinder it is very desirable to know what change in length will be undergone by the tube and casting due to the compression from their exterior envelopes; and, therefore, you will measure as carefully as practicable the length of tube and casting before and after the assemblage of the cylinder.

DISMANTLING THE CYLINDER.

The A and B hoops will be cut longitudinally until separation takes place. After the hoops are removed and the dimensions of the remaining compound cylinder have been measured, if it is found that the tube practically resumes its original dimensions prior to placing the hoops, the tube will be taken out of the casting by means of longitudinal cuts, so as to leave the latter intact for examination and measurement. On the other hand, should the casting show a more perfect restoration than the tube, then the casting will be removed by means of heat. This alternative is scarcely to be anticipated.

TESTS.

After dismantling the cylinder slices will be taken off from one end of each, and the following test specimens taken out and sent to the commanding officer of Watertown arsenal.

HOOPS.

Four tangential extension specimens, 6 inches long between shoulders (see blue print), one from rear outside, one from rear inside, and two from middle of thickness of each hoop.

CASTING.

The slice to be taken from same end as the ring formerly tested. Two tangential extension specimens next the bore, as long between shoulders as the material will admit of. Three tangential compression specimens, 12 inches long, one inside, one outside, and one middle.

Two radial compression specimens, as long as practicable.

Three tangential tensile specimens, one outside, one inside, and one middle.

TUBE.

Three tangential extension specimens, 3 inches long between shoulders, one inside, one outside, and one middle, if practicable.

Three tangential compression specimens, 5 inches in length, one inside, one outside, and one middle, if practicable.

Two radial compression specimens, as long as practicable.

The drawings furnished the commanding officer, Watertown arsenal, showing position of specimens, should have indicated on them, besides the marks on specimens, that the specimens are taken *after* unhooping.

Very respectfully, your obedient servant,

S. V. BENÉT,
Brig. Gen. Chief of Ordnance.

Computations of elastic strength of experimental cylinder from 12-inch breech-loading rifle hooped and tubed.

[Data furnished by the Ordnance Office from the physical tests of the metal made before hooping.]

Tube. (Whitworth steel.)	Cast iron body.	Hoops A^x and B^x. (Midvale steel.)
$\theta_0 = \rho_0 z$ 21.5 tons…….	$\theta_1 = 6$ tons……………	$\theta_2 = \theta_3$ = 22 tons…….
$s_0 = .00\ 15$ inch ……….	$s_1 = .00075$ inch………	$e_2 = e_3 = .0017$ inch…….
$E_0 = 14333.$ tons ………	$\rho_1 = 10$ tons………….	$E_2 = E_3 = 12941.$ tons….
	$c_1 = .00125$ inch……..	
	$E_1 = 8000$ tons………	

Computations.

[Values of P.]

[Capt. Charles S. Smith.]		[Capt. D. A. Lyle and Lieut. H. D. Borup.]	
Tons.	*Tons.*	*Tons.*	*Tons.*
$P_3(^1) = 3.7585$	$\therefore P_3 = 3.7585$	$P_3(^1) = 3.7587$	$\therefore P_3 = 3.7587$
$P_2(^1) = 7.7500$		$P_2(^1) = 7.75049$	
$P_2(^2) = 8.9082$	$\therefore P_2 = 7.7500$	$P_2(^2) = 8.9089$	$\therefore P_2 = 7.75049$
$P_1(^1) = 12.221$		$P_1(^1) = 12.2214$	
$P_1(^2) = 12.151$	$\therefore P_1 = 12.151$	$P_1(^2) = 12.1509$	$\therefore P_1 = 12.151$
$P_0(^1) = 21.515$		$P_0(^1) = 21.5159 +$	
$P_0(^2) = 20.191$	$\therefore P_0 = 20.191$	$P_0(^1) = 20.19111 +$	$\therefore P_0 = 20.19111$

[Values of (P + *p*.)]

[Capt. Charles S. Smith.]		[Capt. D. A. Lyle and Lieut. H. D. Borup.]	
$(P_1 + p_1)^{(\theta)} = 11.704$		$(P_1 + p)^{(\theta)} = 11.704$	
$(P + p)^{\rho} = 7.0225$	$\therefore (P_1 + p_1) = 7.0225$	$(P_1 + p)^{\rho} = 7.0224 +$	$\therefore (P_1 + p_1) = 7.0224$
$p_3 = .42066 \times$		$p_3 = 0.42064 \times p_2$	
		$p_2 = 0\ 20090 \times p_1$	
$p_1 = -6.4041$	$\therefore P_1 + p_1 = 5.6879$	$p_1 = -6.4645$	$\therefore P_1 + p_1 = 5.6864$
	Diff. $= (-)\ 1.3346$		Diff. $= (-) 1.3360$
$(P_2 + p_2)^{(\theta)} = 11.529$		$(P_2 + p_2)^{(\theta)} = 11.526$	
$(P_2 + p_2)^{\rho} = {}^*9.8246$ (9.2846) ?	$\therefore (P_2 + p_2) = 9.8246$	$(P_2 + p_2)^{\rho} = 9.2833$	$\therefore (P_2 + p_2) = 9.2833$
$p_2 = -1.2986$	$\therefore P_2 + p_1 = 6.4514$	$p_2 = 1.2987$	$\therefore P_2 + p_2 = 6.45179$
	Diff. $= -3.3732$		Diff. $= (-) 2.83151$
$(P_3 + p_3)^{\theta} = 12.986$		$(P_3 + p_3)^{(\theta)} = 12.987 +$	
$(P_3 + p_3)^{\rho} = 9.6744$	$\therefore P_3 + p_3 = 9.6744$	$(P_3 + p_3)^{\rho} = 9.6748$	$\therefore (P_3 + p_3) = 9.6748$
$p_3 = -.54627$	$\therefore P_3 + p_3 = 3.2122$	$p_3 = -0.5456$	$\therefore P_3 + p_3 = 3.2131$
	Diff. $= 6.4622$		Diff. $= (-) 6.4617$

*Clerical inversion probably writing 9.82, &c., instead of 9.28, &c.

SHRINKAGES.

[Values of ϕ.]

[Capt. Chas. S. Smith.]	[Capt. D. A. Lyle and Lieut. H. D. Borup.]
$\phi_1 = -.000499 + ''.0007332 = +.000233.$	$\phi_1 = -''.000490915 + ''.000723083 = +''.000232168.$
$p_1 = -11.5032.$	$p_1 = -11.5048.$
$\phi_2 = +.00004777 + .001700 = ''.0017477.$	$\phi_2 = +.000047681 + ''.0017 = +''.001747681 +.$
$p_2 = -4.30845.$	$p_2 = -4.2990 +.$
$\phi_3 = -''.0000941 + 001700 = +.0016059.$	$\phi_3 = -''.000090743 + ''.0017 = +.001609257.$

[Values of $\frac{\Delta R}{R}$]

TANGENTIAL.

System at rest.	System in action.	System at rest.	System in action.
$\frac{\Delta R_0}{R_0}=-.001215.$ $\frac{\Delta R_1}{R_1}=-.000452.$	$\frac{\Delta R_0}{R_0}=+.0012479.$ $\frac{\Delta R_1}{R_1}=+.000733.$	$\frac{\Delta R_0}{R_0}=-.0012146.$ $\frac{\Delta R_1}{\Delta R_1}=-.00045241.$	$\frac{\Delta R_0}{R_0}=+.0012478.$ $\frac{\Delta R_1}{R_1}=+.00073185+.$

RADIAL.

	$\frac{d\,\Delta R_0}{d\,R_0}=-.00150.$ $\frac{d\,\Delta R_1}{d\,R_1}=-.00125.$		$\frac{d\,\Delta R_0}{d\,R_0}=-.0015103.$ $\frac{d\,\Delta R_1}{d\,R_1}=-.0012498.$

TANGENTIAL.

$\frac{\Delta R_2}{R_2}=+.0013755.$ $\frac{\Delta R_3}{R_3}=+.0014496.$	$(EL)\frac{\Delta R_2}{R_2}=+.00170.$ $(EL)\frac{\Delta R_3}{R_3}=+.0017.$	$\frac{\Delta R_2}{R_2}=+.0013750.$ $\frac{\Delta R_3}{R_3}=+.0014532.$	$\frac{\Delta R_2}{R_2}=+.0017020.$ $\frac{R_3}{R_3}=+.001700.$

ASSEMBLAGE.

First stage of experiments.

INSERTION OF STEEL TUBE IN CAST-IRON BODY.

Dimensions before assembling.

Measurements.	Tube.				Casting.			
	Prescribed.	Actual.	Variations.		Prescribed.	Actual.	Variations.	
			Allowed.	Actual.			Allowed.	Actual.
	Inches.	*Inches.*	*Inches.*	*Inches.*	*Inches.*	*Inches.*		*Inches.*
Interior diameter..	13.5	13.5006	±.002	+.0006	20.00	19.9993	±.002	−.0007
Exterior diameter.	*20.0046	20.0053	$\left\{ \begin{matrix} +0.000 \\ -.002 \end{matrix} \right\}$	+.0007	39.3493	39.3532	§+.08	+.0039
Lengths...........	9.5	†9.496	±0.01	−.004	‡9.5	‡9.4998	±.01	−.0002

* Prescribed maximum, 20.0052; prescribed minimum, 20.0032; desired, 20.0046.
† Interior lengths.
‡ Exterior lengths.
§ Enough metal left to finish in subsequent operations.

EXPANDING CAST-IRON BODY.

A gas-heater was used for this purpose very similar to the one heretofore described, and figured in the construction report upon the 12-inch M. L. R. mortar, except that the axis of the heater was *vertical* instead of horizontal.

This heater had 14 arms, carrying 5 flaring burners each, or 70 burners in all, for heating the exterior of the cylinder, and had 11 sets of 4 burners each, or 44 burners, on the spindle for heating the interior.

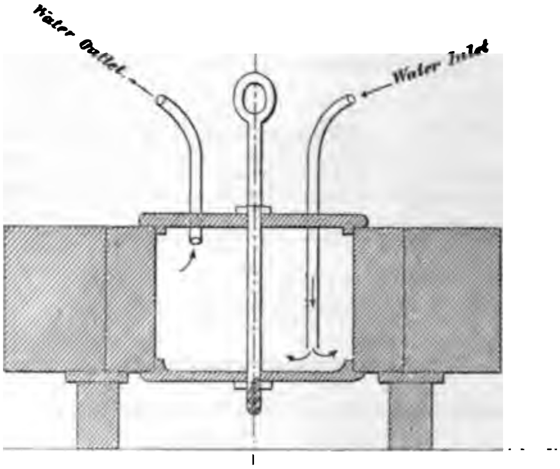
The heater was arranged so that it could be hoisted up and removed from the cylinder by a fall and tackle.

The cylinder was mounted upon an iron ring supported by a cast-iron cylinder.

The position of the cast-iron body in hoisting is shown in the annexed figure, with the gas-heater removed and the tube section inserted. The diagram also shows the arrangement for keeping the tube cool by a current of water.

The heater and section of tube with cooling apparatus were both handled by blocks and tackle rolling on an overhead rail.

Insertion of tube section in cast-iron body.



Vertical section showing arrangement for cooling interior of bore, and position of cast-iron body for heating, with the heater omitted.

Cylinder—details of heating, May 21, 1885.

	h.	*m.*	*s.*
Gas lighted	10	41	30
Blast on	10	41	40
Blast adjusted	10	41	50
Minimum wire [length = 20.005 inches] entered at (loosely)	10	54	0
Trial wire [length = 20.042]			
Gas heater hoisted for first trial measurement	11	22	30
put back	11	23	20
hoisted for second trial measurement	11	34	0
returned	11	34	40
finally removed	11	45	0
Maximum wire [length = 20.045] (tight fit on Nos. 1 and 3):			
No. 1	11	45	30
No. 3	11	45	40
Gas out	11	45	45
Measurements of length on exterior taken by—			
Noonan on No. 1 diameter	11	46	50
Lieutenant Borup on No. 3 diameter	11	46	26
Lieutenant Borup on No. 7 diameter	11	47	10
Captain Lyle on No. 3	11	47	2
Captain Lyle read off at	11	53	0
Section steel tube in place	11	47	30

Measurements of openings between tube and casting on diameters at right angles to each other.

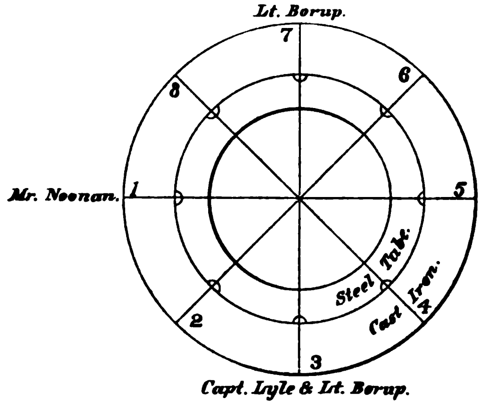
	Inches.
On No. 1 diameter:	
At No. 1	=.019+
At No. 5	=.008+
On No. 3 diameter:	
At No. 3	=.005+
At No. 7	=.020+ maximum.

Time.

	h.	m.	s.
Time at end of these measurements	11	52	0
Section of tube hot between Nos. 3 and 5	11	59	0
Brass thickness gauge = .01 inch loose between Nos. 1-8	12	55	0
tight between Nos. 1-8	1	9	0
Tube and casting in contact at No. 3	1	23	0
Brass thickness gauges = .007 inch between Nos. 1-8	1	25	0
.004 inch tight fit between Nos. 1-8	1	43	0
.003 inch tight fit between Nos. 1-8	1	52	0
.002 inch tight fit between Nos. 1-8 and all around	2	5	0
.002 inch tight fit at No. 1 (maximum opening).	2	12	0
Tube and casting in contact all around (maximum opening one place = .001 inch)	2	26	0
Casting cool	5	15 pm.	
Gas pressure inches..			.95
Gas consumed cubic feet..		772	

Résumé.

Time of heating	1	3	30
Time of cooling	5	30	0
Total duration of experiment	6	33	30
Time from insertion of tube until casting closed on it	2	38	30



EXPERIMENTAL CYLINDER FOR 12-INCH HOOPED AND TUBED B. L. R.

Temperature of water in bore of section of steel tube.

[Object: Insertion of steel tube in cast-iron body; Date, May, 21, 1885; hydrant temp., = 55° F.; water-rate (gals per min.) 9.]

	From—			To—			Temperature.
	h.	m.	s.	h.	m.	s.	°F.
Tube section in position in casting				11	47	30	
Hydrant temperature				11	47	35	55
Temperature of water in bore:							
Temperature=hydrant temperature				11	48	0	55
	11	48	0	11	51	0	55
				11	52	0	56.6
				11	53	0	57.5
					54		58
					55		58
					56		58.5
					57		58.5
					58		58.5
					50		59
Stationary	11	59	0	12	13		59
				12	14		58.75
Both inclusive	12	14	0	12	22		58.75
				12	23		58.5
Both inclusive	12	23	0	12	45		58.5
				12	46		58
Both inclusive	12	46	0	1	48	0	58
				2	07		58
				2	30		57.5
				3	15		57
				3	45		56.5
				4	0	0	56
				4	25	0	55.5
				5	15	0	55
				5	30		*55
Experimental cylinder cool				†5	15 p.m.		

* Little less. † May 21.

Résumé.

	h.	m.	s.
Tube section in position in casting	11	47	30
Temperature of water in bore=hydrant temperature	11	47	35
Temperature of water in bore began increasing	11	51	0
maximum and stationary	11	59	0
began decreasing	12	13	0
=hydrant temperature	5	15	0
Cylinder cool	5	15	0
Time after tube in place before temperature of water in bore began to increase	0	3	30
Time temperature increasing	0	8	0
Time temperature, maximum, after tube in position	0	11	30
Time temperature stationary	0	14	0
Time temperature decreasing	5	2	0
Total time of cooling	5	27	30
Rate of flow of water through bore (per minute) ... gallons			9
Total water used in cooling (approximate) ... do			2,947½
Temperature of water at hydrant ... °Fah			55
Maximum temperature of water in bore ... do			59
Maximum rise of temperature in bore ... do			4

MEASUREMENTS FOR EXPANSION.

1.—*Diametral.*

Grand Means:

Exterior diameter of tube cold	20.0454
Interior diameter of casting cold	19.9996
Minimum wire length	20.005
Maximum wire length	20.045
Maximum expansion diametrally	0.0454

Relative expansion diametrally referred to original diameter=19.9996= 2.27 thousandths per 1″

2.—*Longitudinal.*

[All measurements taken on exterior elements.]

	Inches.
Diameter No. 1:	
At No. 1. May 14, exterior length cold [original measurement] (Lieutenant Borup)	9.501
May 21, exterior length cold (Mr. Noonan)	9.503
exterior length hot (Mr. Noonan)	9.5185
Total longitudinal expansion	0.0155
Relative expansion longitudinally [referred to original length, 9.503], 1.06 thousandths per 1″.	
Diameter No. 3:	
At No. 3. May 14, original measurement cold (Lieutenant Borup)	9.501
May 21, exterior length cold (Lieutenant Borup)	9.505
exterior length hot (Lieutenant Borup)	9.522
Total longitudinal expansion	.0215
Relative expansion longitudinally [referred to original length, 9.5005], 2.26 thousandths per 1″.	
At No. 7. Exterior length, original measurement, cold (Lieutenant Borup)	9.501
May 21. Exterior length cold (Lieutenant Borup)	9.5005
Exterior length hot (Lieutenant Borup)	9.521
Total longitudinal expansion	0.0205
Relative expansion longitudinally (referred to original length=9.5005) 2.15+thousandths per 1″.	
At No. 3. May 21. Exterior length between prick punch marks, cold (Captain Lyle)	8.9085
May 21. Exterior length between prick punch marks, hot (Captain Lyle)	8.9190
Total longitudinal expansion	0.0105
Relative expansion longitudinally (referred to original length=8.9085) 1.18 thousandths per 1″ (1.178+).	

Second stage of experiment.—Application of hoop A*x to cast-iron body.*

Dimensions before assembling.

Measurements.	Cast-iron cylinder.				Hoop A*x*.			
	Prescribed.	Actual.	Variations.		Prescribed.	Actual.	Variations.	
			Allowed.	Actual.			Allowed.	Actual.
	Inches.	*Inches.*	*Inches.*	*Inches.*	*Inches.*	*Inches.*	*Inches.*	*Inches.*
Interior diameter	....	....	....	....	39.2	39.2007	±.002	+.0007
Exterior diameter	39.2693	39.2654	+.000 −.002	−.0039	46.0539	46.0168	−.08	−.0371
Lengths	9.5	9.5002	±.01	+.0002	9.	8.999	±.01	−.001

EXPANDING HOOP A*x*.

The gas heater employed for expanding the cast-iron body was used for hoop A*x* by merely adjusting the extensible arms carrying the burners, so as to include the greater diameter of cylinder.

The experimental cylinder was mounted horizontally, as shown in the accompanying sketch, which shows the cylinder with hoop A*x* in position upon it, in its expanded state. Besides simulating the actual operation with the gun, this method of procedure afforded an opportunity to measure the maximum opening between the cylinder and hoop, and to observe the rate of contraction of the hoop.

Brass thickness gauges were used to measure the opening between the hoop and cylinder at the lowest point until the hoop closed and gripped the cylinder. The times were taken at which the opening reached the dimensions of the several gauges, and at the instant the hoop clamped the cylinder. A current of cold water was kept circulating through the bore of the tube section until the whole system was cold. In heating, the hoop was hung with one of its diameters vertical, the same position to be observed in hooping the gun.

See diagram opposite.

Details of heating hoop Ax.

	h.	m.	s.
Gas lighted	10	31	00
Blast turned on	10	31	05
Blast adjusted	10	31	20
Minimum wire [length = 39 '.265 = diameter of cast-iron body] entered at	10	59	20
Trial wire [length = 39".275] entered at	11	04	50
Maximum wire [length = 39".285] entered at	11	10	50
Gas turned off at	11	10	55
Measurements for longitudinal expansion taken between 11h. 10m. 55s. and	11	11	30
Began sliding hoop on	11	11	30
Hoop in position at	11	12	30
Brass thickness gauge = 0".017 entered at	11	15	15
= ".01 entered at	11	17	25
= ".005 entered at	11	19	00
= ".004 entered at	11	19	35
= ".003 entered at	11	19	55
= ".002 did not enter at	11	20	15
= ".001 did not enter at	11	20	25
Water ring over entire hoop at	11	21	00
Heat perceptible half through cast-iron body	11	26	00
Heat barely preceptible to touch at exterior of tube	11	37	00
Tube just perceptibly warm	11	49	00
Hoop cold at	11	49	00
Water off at	12	00	00
Gas consumed	Not taken.		
Color of hoop	Light brown.		

Résumé.

	m.	sec.
Time of heating	39	50
Time of cooling	38	10
Total duration of experiment	78	00
Time after removing from heater until hoop clamped experimental cylinder	9	30
Time after application until hoop closed on cylinder	7	55

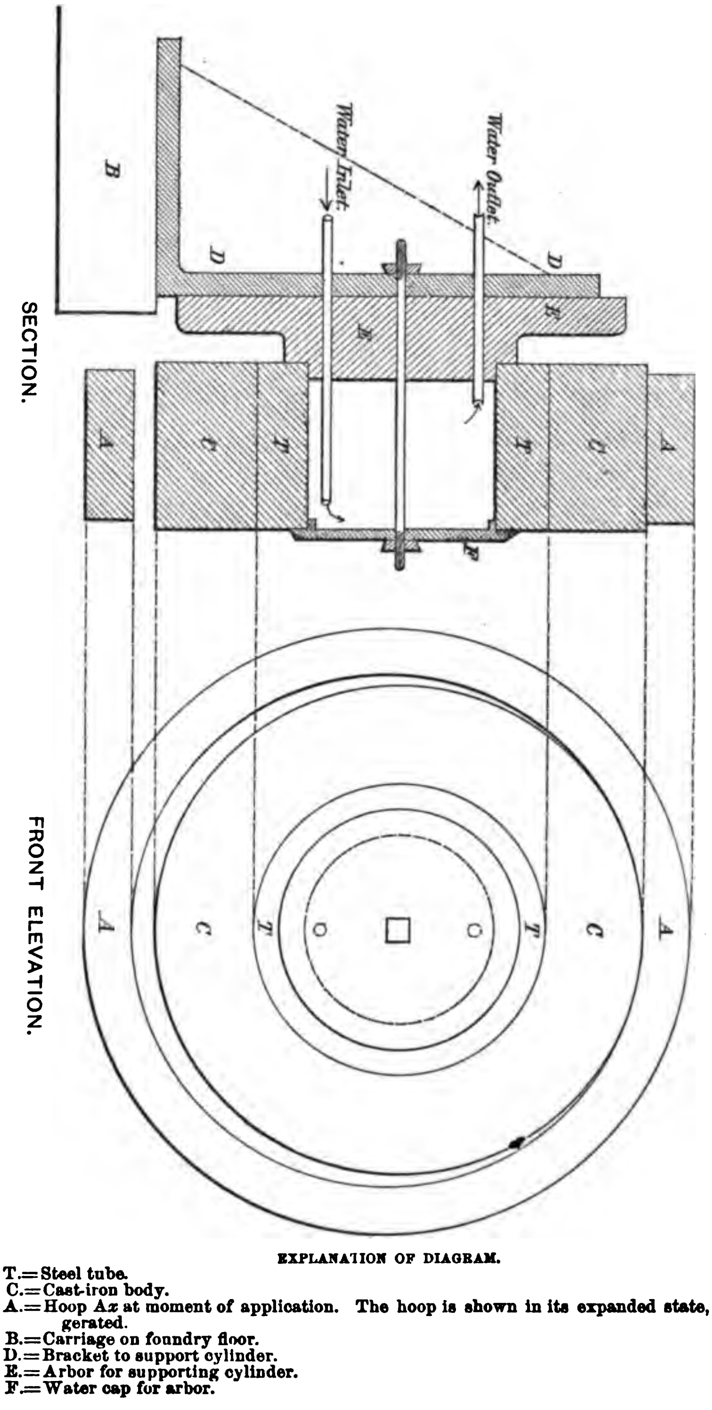
EXPERIMENTAL CYLINDER FOR 12-INCH HOOPED AND TUBED B. L. R.

Temperature of water in bore of section of steel tube.

[Object: Application of hoop *Ax*; date, May 29, 1885; hydrant temperature, 60° F.; water rate (gallons per minute) = 7.8.]

	From—			To—			Temperature.
	h.	m.	s.	h.	m.	s.	°F.
Hoop in position on casting				11	12	30	
Hydrant temperature				11	12	30	60
Temperature of water in bore:							
Temperature = hydrant temperature				11	13	00	60
Temperature	11	13	00	11	28	00	60
Both, inclusive	11	29	00	11	31	00	60.5
Both, inclusive	11	32	00	11	36	00	61
Both, inclusive	11	37	00	11	39	00	61.5
Stationary (both, inclusive)	11	40	00	11	52	00	62
Both, inclusive	11	53	00	11	59	00	61.5
Both, inclusive	12	00	00	12	02	00	61
Both, inclusive	12	03	00	12	10	00	60.5
				12	15	00	62
Hoop, cool				12	15 p.m.		

ARRANGEMENT OF EXPERIMENTAL CYLINDER FROM THE 12-INCH HOOPED AND TUBED B. L. RIFLE, FOR THE APPLICATION OF HOOP A*x*.



EXPLANATION OF DIAGRAM.

T. T.=Steel tube.
C. C.=Cast-iron body.
A. A.=Hoop A*x* at moment of application. The hoop is shown in its expanded state, much exaggerated.
B.=Carriage on foundry floor.
D. D.=Bracket to support cylinder.
E. E.=Arbor for supporting cylinder.
F.=Water cap for arbor.

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Résumé.

	h.	m.	s.
Hoop A*x* in position on casting	11	12	30
Temperature of water in bore = hydrant temperature	11	13	00
Temperature of water in bore began increasing	11	28	00
Maximum and stationary	11	40	00
Began decreasing	11	52	00
Hydrant temperature	12	15	00
Hoop A*x*, cool	12	15	00
Time after tube in place before temperature of water in bore began to increase		17	
Time temperature increasing		12	
Time temperature maximum (after tube in position)		27	30
Time temperature stationary		12	
Time temperature decreasing		19	
Total time of cooling		62	30
Rate of flow of water through bore (per minute) gallons			7.8
Total water used in cooling (approximately) do			460
Temperature of water at hydrant °Fahr			60
Maximum temperature in bore do			62
Maximum rise of temperature in bore do			2

HOOP A*x*.

Limits of diametral expansion.

	Aliquot part of interior diameter.	Resulting expansion.	Resulting interior diameter.
	Thousandths.	*Inches.*	*Inches.*
Interior diameter cold			39.2007
Prescribed limits:			
Maximum	3.5	.1372+	39.3379
Minimum	2.5	.0980+	39.2987
Actual	2.15	.0843	39.2850

Time and rate of expansion and contraction.

1.—DIAMETRAL EXPANSION.

	h.	m.	sec.
Interior diameter hoop A*x* when cold			39.2007
Gas lighted and blast adjusted	10	31	20
Minimum wire (length = 39″.265) entered at	10	59	20
Trial wire (length = 39″.275) entered at	11	04	50
Max. wire (length = 39″.285) entered at	11	10	50

Hence:

Period of heating.	Time of heating.	Total diametral expansion.	Rate of expansion per one inch per minute.
	Minutes.	*Inches.*	*Thousandths.*
First	28	.0643	Nearly 2.3
Second	5.5	.01	1.8 +
Third	6	.01	1.66
Mean			1.92
Total time heating	39.5	.0843	2.13+

2.—DIAMETRAL CONTRACTION.

	h.	m.	s.
Hoop removed from heater at	11	10	50
Maximum opening = .02 inch at	11	10	50
Brass thickness gauge = .017 inch, entered at	11	15	15
Interval after removing from heater until first measurement taken	00	4	25

of cooling.	Time of cooling.		Opening.	Interval of time.	Total diametral contraction.	Rate of contraction per one inch per minute.
	m.	s.	*Inches.*	*Minutes.*	*Inches.*	*Thousandths.*
First	4	25	.017			
Second	6	35	.01	2.16	.007	2.2 +
Third	8	10	.005	1.58	.005	2.1
Fourth	8	45	.004	0.58	.001	1.7
Fifth	9	05	.003	0.33	.001	2.0
Sixth	9	25	nearly .002	0.33	.001+	2.0
Seventh	9	35	Hoop had closed on cylinder.			
Mean				4.98	.016	2.2 +
Total time from entrance of gauge = ".017 thick until hoop closed.				5.16	.017	2.2 +
Total time contracting	9	35	.02	9.58	.02	2.08+

3. COMPARISON.

By times.

	h.	m.	s.
Expansion:			
Minimum wire = 39".265 entered	10	59	20
Maximum wire = 39".285 entered	11	10	50
Time required to expand 0".02		11	30
Contraction:			
Maximum opening of Hoop *Ax* on cylinder = 0".017	11	15	15
Hoop *Ax* closed on cylinder	11	20	25
Time required to contract 0".017		5	10
Hence, assuming rate of contraction to be constant, the time required to contract 0".02		6	42

By measurement.

	Thousandths per 1" per minute.
Expansion:	
Taking the relative expansions, we have for the—	
First period of heating, relative expansion	2.3 nearly.
Second period of heating, relative expansion	1.8
Third period of heating, relative expansion	1.66+
Mean relative expansion	1.92
And taking—	
Total time of heating, then relative expansion	2.13+
Contraction:	
Mean relative contraction for 0".017 opening	3.2
Mean relative contraction for total time of contraction	2.08

4. LONGITUDINAL EXPANSION.

Instrument used.	Observer.	Diameter.		Length of *Ax*.			Relative expansion or expansion per linear inch.*
		No.	At—	Cold.	After heating.	Total expansion.	
						Inches.	
Vernier beam calipers (Navy)	Comdr. Lyon	1	"1" †Probably	9.0005	9.0285 9.0185	0.028 0.018	3.11+ 2 nearly.
Vernier beam calipers (Ordnance).	Mr. Noonan and Lieutenant Borup.	3	"3"	8.9995	9.019	0.0195	2.16+
Beam compasses	Captain Lyle	3	"7"	9.065	9.08	0.15	1.65+

*Referred to original lengths (cold).

†Comdr. Lyon evidently called off the wrong hundredth of an inch, making it 0.028 instead of 0.018. He says that he believes he did make this error, but gives both.

Third stage of experiment—Application of Hoop Bx *to experimental cylinder.*

Dimensions before assembling.

Measurements.	Hoop Ax.				Hoop Bx.			
	Prescribed.	Actual.	Variations.		Prescribed.	Actual.	Variations.	
			Allowed.	Actual.			Allowed.	Actual.
	Inches.	*Inches.*	*Inches.*	*Inches.*	*Inches.*	*Inches.*	*Inches.*	*Inches.*
Interior diameter					45.9	45.9	±.002	0
Exterior diameter	Mean. 45.9739	45.9767	+.000 −.002	+.0028	53.7	53.6963	±.002	−.0037
Lengths	9.0	8.996	±.01	−.004	9.0	9.0	+.01	0

EXPANDING HOOP B*x* BEFORE APPLICATION.

This hoop was expanded in the same gas-heater as Hoop A*x*, but on account of the larger diameter the circumferential burners were farther apart and the heating was slower. Both hoops were held in a loop-sling similar to the one used for the hoops put on the 12-inch M. L. R. mortar. This hoop attained a higher temperature than Hoop A*x*, but neither was hot enough to exceed a "brown" color.

Details of heating (Hoop B*x*)*—Date June* 10, 1885.

	h.	m.	s.
Gas lighted	9	31	10
Blast turned on	9	31	20
Blast adjusted	9	31	30
Minimum wire (length = 45.977 = diameter of exterior of hoop A*x*) entered	10	22	30
Trial wire (length = 45.987) entered	10	30	0
Maximum wire (length = 45.997) entered:			
Horizontal	10	35	30
Vertical	10	38	15
Gas turned off	10	38	25
Measurements for longitudinal expansion taken between 10h 38m 20s and	10	39	30
Began sliding hoop on		Lost.	
Hoop in position	10	40	20
Brass thickness gauge = ″.03 entered (tight)	10	42	30
= .02 entered (tight)	10	44	30
= .015 entered (tight)	10	45	45
= .01 entered	10	46	50
= .005 entered	10	47	50
= .002 would not enter	10	48	30
Water ring over entire hoop	10	50	0
Could not bear hand on Hoop A*x* (heat had also extended radially 2 inches from exterior of casting)	10	51	0
Heat barely perceptible at middle of casting	10	57	30
Heat barely perceptible at two-thirds thickness from exterior of casting	11	01	0
Hoop B*x* cold on exterior, heat barely perceptible on interior, and A*x* warm	11	22	0
Casting warm except near tube, heat in A*x* barely perceptible	11	23	0
Hoop B*x* cold	11	23	0
Water off	11	45	0

Gas pressure, difference in columns:		
While burning	inches	1.1
After turned off	do	1.8
Gas consumed	cubic feet	1017
Hydrant temperature of water	degrees	62
Rate of water per minute	gallons	9
Maximum rise of temperature in bore	degrees	1¼
Color of hoop		Brown.

Résumé.

	h.	m.	s.
Time of heating		66	45
Time of cooling		44	45
Total duration of experiment from lighting gas until water turned off Hoop Bx	2	13	50
Time after removing from heater until hoop clamped experimental cylinder.		10	45
Time after application until hoop closed on cylinder		8	40

Temperature of water in bore of section of steel tube.

Object: Application of Hoop B*x*. Date: June 10, 1885. Hydrant temperature=62°. Water rate (gallons per minute): 9.

	From—			To—			Temperature.
	h.	*m.*	*s.*	*h.*	*m.*	*s.*	*Degrees F.*
Hoop in position on Hoop A*x*				10	40	20	
Hydrant temperature				10	40		62
Temperature of water in bore:							
Temperature=hydrant temperature				10	41		62
Temperature (both inclusive)	10	41	0	10	59	0	62
(both inclusive)	11	0	0	11	03		62.5
(both inclusive)	11	04	0	11	14		63
(both inclusive)	11	15		11	30		63.5
(both inclusive)	11	31		11	43		63
(both inclusive)	11	44		11	51		62.5
				11	52		62
Hoop cool				11	23		

Résumé.

	h.	m.	sec.
Hoop B*x* in position on cylinder	10	40	20
Temperature of water in bore=hydrant temperature	10	41	0
Temperature of water in bore, began increasing	11	..	..
maximum and stationary	11	15	0
began decreasing	11	31	..
=hydrant temperature	11	52	..
Hoop B*x* cool	11	23	..
Time after hoop in place before temperature of water in bore began to increase	0	19	40
Time temperature increasing	0	15	0
Time temperature, maximum (after hoop in position)	0	34	40
Time temperature, maximum and stationary	0	15	..
Time temperature, decreasing	0	22	..
Total time of cooling:			
hoop	0	42	40
cylinder	0	71	40
Rate of flow of water through bore ... gallons per minute	9		
Total water used in cooling (approximate) ... gallons	648		
Temperature of water at hydrant ... degrees Fahrenheit	62		
Maximum temperature in bore ... do	63.5		
Maximum rise of temperature in bore ... do	1.5		

Limits of diametral expansion.

	Aliquot part of interior diameter.	Resulting expansion.	Resulting interior diameter.
	Thousandths.	*Inches.*	*Inches.*
Interior diameter, cold			45.9
Prescribed limits:			
Maximum	3.5	0.16065	46.06065
Minimum	2.5	0.11475	46.01475
Actual limits	2.1132	0.097	45.997

Time and rate of expansion and contraction.

1.—DIAMETRAL EXPANSION.

Interior diameter hoop *Bx* when cold ....inches.. 45.9

	h.	*m.*	*sec.*
Gas lighted and blast adjusted	9	31	30
Minimum wire (length = 45.977) entered at	10	22	30
Trial wire (length = 45.987) entered at	10	30	0
Maximum wire (length = 45.997) entered:			
Horizontally at	10	35	30
Vertically at	10	38	15

Hence:

Period of heating.		Time of heating.	Total diametral expansion.	Rate of expansion per 1 inch per minute.
		Minutes.	*Inches.*	*Thousandths.*
First		51	.077	1.50+
Second		7.5	.01	1.33+
Third	horizontal	5.500	.01	1.81
	vertical	8.250	.01	1.21
	mean	6.875	.01	1.45+
First and second		58.5	.087	1.487+
Second and third	horizontal	13.000	.02	1.53
	vertical	15.750	.02	1.26+
	mean	14.375	.02	1.39+
Total time of heating		66.75	.097	1.45+

2.—DIAMETRAL CONTRACTION.

	h.	*m.*	*sec.*
Gas turned off	10	38	25
Thickness gauge =.03 inch, tight fit	10	42	30
Interval after gas off until measure taken		4	05

Period of cooling.	Time of cooling.		Opening.	Interval of time.	Total diametral contraction.	Rate of contraction per 1 inch per minute.
	m.	*sec.*	*Inches.*	*Minutes.*	*Inches.*	*Thousandths.*
1	4	05	.03			
2	6	05	.02	2	.01	5
3	7	20	.015	1.25	.005	4
4	8	25	.01	1.08	.005	4.6+
5	9	25	.005	1	.005	5
Mean						4.65
Total				5.33	.025	4.69+

3.—COMPARISON.

By times.

	h.	*m.*	*sec.*
Expansion:			
Minimum wire = 45.977 entered at	10	22	30
Maximum wire = 45.997 entered at	10	35	30
Time required to expand .02 inch		13	
Contraction:			
Maximum opening of hoop *Bx* on hoop *Ax* = .02 inch at	10	44	30
Hoop *Bx* closed on *Ax* at	*10	48	20†
Time required to contract .02 inch		4	

---

* Tried to insert .002-inch gauge but failed; and hoop had closed so that the .001-inch gauge would not enter before observers could change and apply gauges; hoop closed probably about 10.49 a. m.

Hence, according to the intervals of time, the rate of contraction is about three times as great as the rate of expansion.

By measurement.

	Thousandths per 1 inch per minute.
Expansion:	
Taking the relative expansion, we have for the first period of heating relative expansion	=1.5+
Second period of heating, relative expansion of	1.33+
Third period of heating (mean), relative expansion	1.45+
Mean relative expansion	1.426+
And taking, total time of heating, then relative expansion	=1.450+
Contraction:	
Mean relative contraction	=4.69

Hence, according to the measurements, the rate of contraction is a little greater than three times the rate of expansion.

4.—LONGITUDINAL EXPANSION.

Instrument used.	Observer.	Diameter.		Length of hoop B*x*.			*Relative expansion or expansion per linear inch.
		No.	At.	Cold. (*b*)	After heating. (*a*)	Total expansion. (*a–b*)	
				Inches.	*Inches.*	*Inches.*	*Thousandths.*
Beam compasses	Captain Lyle	2	"2"	8.995	9.02	.025	2.77+
Vernier beam calipers (Navy).	Commander Lyon	4	"4"	9.000	9.018	.018	2.00
Vernier beam calipers (South Boston Iron Works).	Mr. Noonan	4	"4"	9.000	9.015	.015	1.66+
Vernier beam calipers (Ordnance).	Lieutenant Borup and Mr. Casey.	2	"6"	9.000	9.017	.017	1.88+
Mean of all four observations							2.07
Mean of last three							1.846+
Mean of two observations on diameter 2 (at "2" and "6")							2.32
Mean of two observations on diameter 4 (at "4")							1.83

*Referred to original lengths (cold).

DISMANTLING.

Fourth stage of experiment: Removing hoop B*x from experimental cylinder.*

The cylinder was placed on edge upon the planer and a slot 0.5″ wide was cut lengthwise of the hoop, beginning on the exterior, until the uncut metal was reduced to about 0.3″ in thickness, when rupture took place with a report closely resembling a pistol-shot. The slot was made on diameter No. 1, at the end marked "1". One of the "scored" diameters was selected, in order to get a point where the interior length was known from previous measurements, for use in determining the contraction of the web or fin of uncut metal after rupture. This method of procedure has this disadvantage, *i. e.*, that the interior and exterior diameter at this point measured after unhooping are somewhat distorted, due to the contraction of the uncut metal, and are not directly comparable with those previously taken at the same place.

It would probably be better to determine and mark in advance a point, say, half-way between diameters 1 and 2, and measure the interior length at that place for use as above stated. This would enable all measures of interior and exterior diameters to be taken after rupture for direct comparison with those previously obtained.

A 12″ Brown and Sharpe scale was used for measuring the depth of the slot. The width of the slot was measured from time to time by a taper-gauge, reading directly to .005″, with about 0.1″ between the graduating divisions, so that the widths could easily be estimated to within ±.002 of their actual dimensions.

The widths of slot were measured at each end of the cylinder, those marked as taken "at A" being taken on the "face" in all cases, and those "at B" were taken at the opposite end of the slot.

The measurements in column marked "top" were taken on the exterior and at the same point throughout. Those in column marked "middle" were taken half-way between the exterior and the bottom of the cut, and of course changed with the depth of cut. The column marked "bottom" contains the readings taken at the bottom of the cuts whose depths are given in the first column. These measurements were taken to observe the form assumed by the cut under the hoop-stress as the slotting proceeded.

Measurements of width of slot in cutting off hoop B*x*.*

Depth of slot.	Width of slot—			
	At A		At B.	
	Top.	Bottom.	Top.	Bottom.
	Inches.	*Inches.*	*Inches.*	*Inches.*
0.217	.495	....	.497	....
0.6	.4975	....	.500	....
0.8 (scant)†	.501	.4975	.501	.503
1.	.503	.495	.501	.502
1.5	.507	.496	.505	.499
2.5	.545	.498	.545	.502
3.0	.589	.499	.589	.504
3.5	.670 (scant)	.503	.669	.503
3.58 after rupture	.767	.596	.766	.608

---

* Measured from exterior of B*x*.

† Edge of tool broken off; tool ground to width of .5″ as nearly as practicable, and used until end of experiment. From this time oil was used freely to keep the tool from losing its temper by heating.

Miscellaneous measurements (B*x*).

Width of slot after rupture (hoop removed):		
At top	inches	.665
At middle	do	.65
At bottom	do	.514
Width of seam, or line of rupture hoop in place = $\frac{1}{16}''$	do	.0625
Exterior diameter B*x*, original	do	53.6963
Interior diameter B*x*, original	do	45.9
Difference	do	7.7963
Half difference = thickness of B*x* (original)	do	3.896
Depth of slot	do	3.58
Difference = thickness metal uncut before rupture	do	.316
Measured thickness of metal uncut after rupture:		
At A	do	.2965
At B	do	.311
Mean thickness metal uncut after rupture =	do	.304
Contraction of thickness at line of rupture = (.316″—.304″) =	do	.012
Contraction of thickness	per cent	3.7+
Original length	inches	9.
Length after rupture	do	8.883
Contraction of length	do	.117
Contraction of length	per cent	1.3
Area of section before rupture	square inches	2.844
Area of section after rupture	do	2.700+
Contraction of area	per cent	5.+

Fifth stage of experiment: Removing hoop Ax from the cast-iron body.

This hoop was removed in the same manner as hoop B*x*. The report when the uncut metal broke was sharp, but not quite so loud as that accompanying the rupture of hoop B*x*.

Measurements of width of slot in cutting off hoop Ax.

Depth of slot. Diameter No. "1" on "1."	Width of slot—					
	At A.			At B.		
	Top.	Middle.	Bottom.	Top.	Middle.	Bottom.
	Inches.	*Inches.*	*Inches.*	*Inches.*	*Inches.*	*Inches.*
.2 inch	.492	....	....	.495	....	....
1 inch	.497	....	.493	.501	....	.493
1.5 inches	.506	....	.493	.508	....	.495
2.5 inches	.558	.543	.496	.556	.542	.497
3.0 inches	.622	.603	.501	.624	.605	.498
3.1 inches, hoop ruptured	.711	.693	.578	.707	.684	.573

Miscellaneous measurements (Ax.)

Width of slot after rupture, hoop removed:		
At top	inches	.628
At middle	do	.620
At bottom	do	.500
Width of seam, or line of rupture, hoop in place ($\frac{1}{20}''$)		.05
Exterior diameter of A*x*, original		46.0168
Interior diameter of A*x*, original		39.2007
Difference		6.8161
Half difference = thickness of A*x*, original		3.40805+
Depth of slot		3.1
Difference = thickness metal uncut before rupture		.308
Measured thickness of metal uncut after rupture:		
At A		.246
At B		.231
Mean thickness metal uncut after rupture		.2385
Contraction of thickness at line of rupture = (.308″ — .2385″) =		.0695
Contraction of thickness	per cent	22.56
Original length	inches	9.
Length after rupture	do	8.902
Contraction of length	do	.098
Contraction of length	per cent	1.08
Area of section before rupture	square inches	2.772
Area of section after rupture	do	2.118+
Contraction of area	do	0.654
Contraction of area	per cent	23.5+

Sixth stage of experiment: Removing cast-iron body from steel tube.

The cast-iron body was cut off in the same manner as hoops B and A, in accordance with telegraphic instructions from the Chief of Ordnance, U. S. A. The uncut metal on the interior broke with a very faint but audible report. The opening of the seam or line of rupture was too slight to be measured.

Measurements of width of slot in cutting off cast-iron cylinder.

[Width of tool =]

Depth of slot on diam. No. 1 on "1."	Width of Slot.					
	At A.			At B.		
	Top.	Middle.	Bottom.	Top.	Middle.	Bottom.
	Inches.	*Inches.*	*Inches.*	*Inches.*	*Inches.*	*Inches.*
.25 inch	.497	....	....	.487	....	....
2 inches scant	.499	.487	.492	.495	.485	.495
4 inches	.501	.494	.492	.497	.494	.493
6 inches	.502	.495	.491	.498	.495	.493
9 inches	.509	.500 scant	.492	.507	.497	.493
9.35 inches ruptured	.523	.512	.502	.518	.509	.508

Very light report.

Micellaneous measurements (cast-iron cylinder).

Width of slot after rupture, cylinder removed:	
At A:	
At top ... inches..	.511
At middle ... do....	.505
At bottom ... do....	.497
At B:	
At top ... inches..	.506
At middle ... do...	.503
At bottom ... do...	.496
Width of seam or line of rupture, cylinder in place ...	(too minute to measure)
Exterior diameter of cast-iron cylinder, original	39.2635
Interior diameter of cast-iron cylinder, original	20.0031
Difference	19.2604
½ difference=thickness of cylinder, original	9.6302
Depth of slot:	
At B	9.4*
At A	9.35*
Difference=thickness of metal uncut before rupture:	
At B	.2302
At A	.2802
Mean thickness of metal uncut before rupture	.2552
Measured thickness of metal uncut after rupture:	
At A	.256
At B	.242
Mean thickness of metal uncut after rupture	.249
Contraction of thickness at line of rupture (″.2552—″.249)	.0062
Contraction of thickness ... per cent..	2.429
Original length	9.4982
Length after rupture ... inside..	9.496
Contraction of length	.0022
Contraction of length ... per cent..	.02
Area of section before rupture ... square inches..	2.4239
Area of section after rupture ... do....	2.3645
Contraction of area ... do....	.0594
Contraction of area ... per cent..	2.45

---

* Approximate.

RECAPITULATION.

Absolute and relative expansions.

[The relative expansions are expressed in thousandths per linear inch of the original dimensions before heating.]

			Casting.	Hoop Ax.	Hoop Bx.
Total time of heating			1h 8m 30s	39m 50s	1h 6m 45s
Time of cooling			5h 30m	38m 10s	44m 45s
Time after application until closed			2h 38m 30s	7m 55s	8m 40s
Original interior diameter		inches	19.9993	39.2007	45.9
Diametral expansion:					
Maximum		inches	.0454	.0843	.097
Relative thousandths per 1 inch			2.27	2.154+	2.113+
Longitudinal expansion:					
Total	Mr. Noonan (at "1")	inches	.0155	....	.015
Relative		thous. per 1 inch.	1.06	....	1.66+
Total	Lt. Comd'r Lyon (at "1")	inches	....	.018	.018
Relative		thous. per 1 inch	....	2.0 nearly	2.
Total	Capt. Lyle (at "3")	inches	.0105	at "7". .015	.025
Relative		thous. per 1 inch	1.18	1.65+	2.77+
Total	Lt. Borup and Mr. Casey (at "3")	inches	.0215	.0195	.017
Relative		thous. per 1 inch	2.26	2.16+	1.88+
Total	Lt. Borup and Mr. Casey (at "7")	inches	.0205	....	....
Relative		thous. per 1 inch	2.15	....	....

Relative diametral expansion and contraction per linear inch per minute for the last .02 inch of absolute expansion.

		Hoop Ax.	Hoop Bx.
Expansion:			
Mean (of periods)	thousandths per 1 inch per minute	1.73+	1.39+
Using total time of heating	do	2.13+	1.45+
Contraction:			
Mean (of periods)	thousandths per 1 inch per minute	3.2 +	4.65
Using total time of contracting	do	2.08+	4.69+
Time required to expand last .02 inch		11m 30s	13m
Time required to contract same .02 inch		6m 42s	4m

TEST SPECIMENS.

[Diagrams appended.]

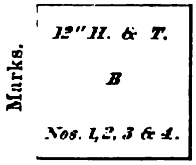
These were taken from the hoops, cast-iron body, and tube section, *after unhooping*. The specimens were either rough, planed, or turned, and were sent to Watertown Arsenal to be finished and tested.

(1) HOOP B*x* (MIDVALE STEEL).

Four (4) *tangential specimens. Length* 9 *by* 1.2 *inches square.*

No. 1, outside.
No. 2, inside.
Nos. 3 and 4, middle.
See (diagram B.)

"*B.*"

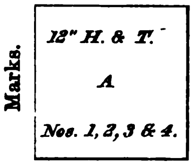


(2) HOOP A*x* (MIDVALE STEEL).

Four tangential tension specimens. Length 9 *by* 1.2 *inches square.*

No. 1, outside.
No. 2, inside.
Nos. 3 and 4, middle.
(See diagram A.)

A.



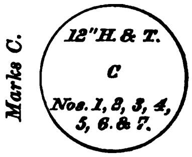
(3) CAST-IRON BODY.

Two tangential tension specimens. Length 31 *by* 1.2 *inches diameter.*

Nos. 1 and 2, both inside.

Three tangential compression specimens. Length 12 *by* 1.2 *inches diameter.*

No. 3, outside.
No. 4, middle.
No. 5, inside.

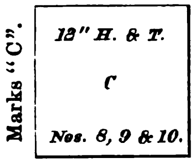


Two radial compression specimens. Length 9.6 *by* 1.2 *inches diameter.*

Nos. 6 and 7, opposite sides of center.

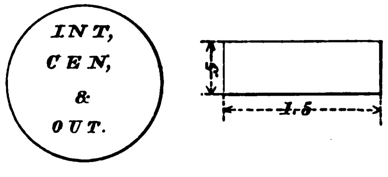
Three tangential tenacity specimens. Length 4.1 *by* 1.25 *inches square.*

No. 8, inside.
No. 9, middle.
No. 10, outside.
(See diagram C.)



Three (3) *disks for hardness and density,* 5 *inches by* 1.5 *inches diameter*

Marks:



These disks were taken on a radius, one inside, one outside, and the other from the middle of the ring.

They were sent to Sandy Hook for test.

The disks were subjected to a pressure of 10,000 pounds in the testing-machine at Sandy Hook, with the following results, as communicated by Capt. C. W. Whipple, Ord. Dept., U. S. A., viz:

Specimen marked.	Length of cut.	Hardness.
	Inches.	
INT	0.625	13.65
CEN	0.610	14.60
OUT	0.625	13.65

The specific gravity of the specimens was not given.

(4) TUBE (WHITWORTH STEEL).

Three tangential tension specimens. Length 6 by 1.2 inches square.

No. 1, outside, } from same side of center.
No. 2, inside, }
No. 3, middle, from opposite side of ring.

Three tangential compression specimens. Length 5 by 1.2 inches square.

No. 4, outside, } from same side of center.
No. 5, inside, }
No. 6, middle, from opposite side of ring.

Two radial compression specimens. Length 3.2 by 1.2 inches squares.

No. 7, } from opposite sides of center.
No. 8, }

Marks:
(See diagram T.)

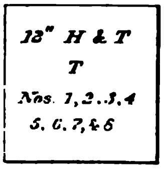
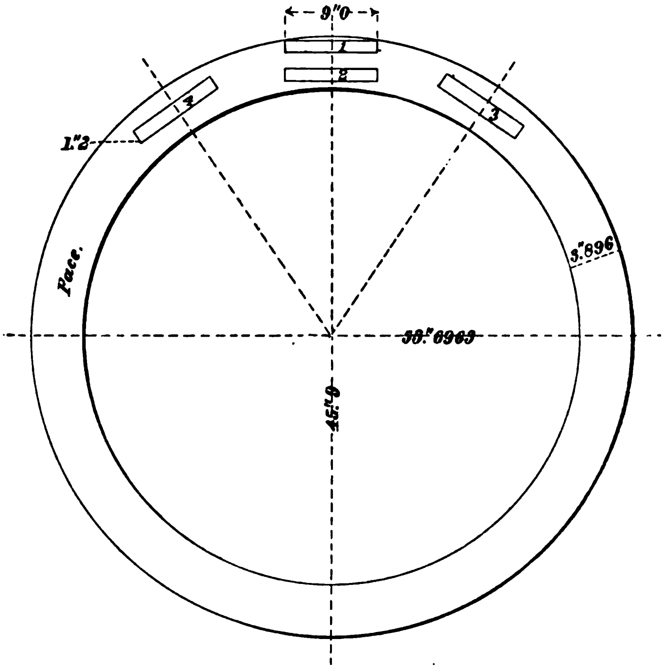


DIAGRAM B.

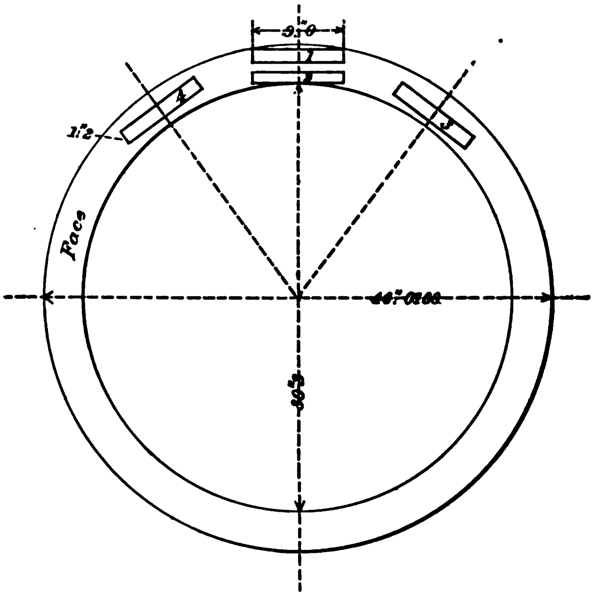
[Showing position of specimens.]



HOOP B (MIDVALE STEEL).

DIAGRAM A.

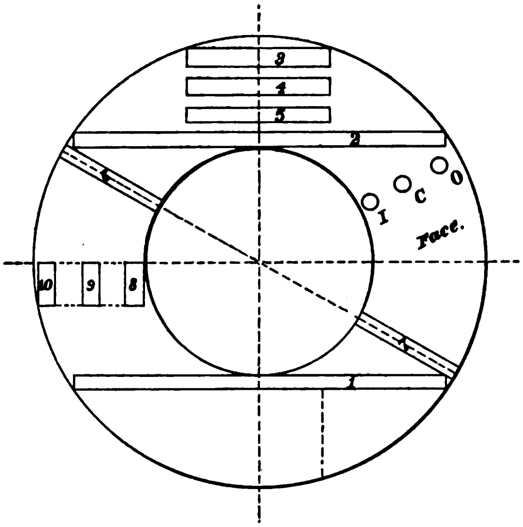
[Showing position of specimens.]



HOOP A (MIDVALE STEEL).

DIAGRAM O.

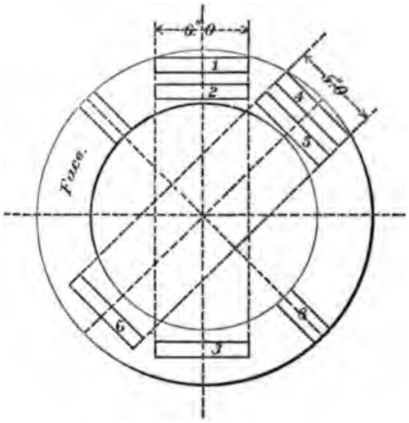
[Showing position of specimens.]



CAST-IRON BODY.

DIAGRAM T.

[Showing position of specimens.]



TUBE (WHITWORTH STEEL).

REMARKS ON HEATING THE HOOPS.

It will be noted that $66^m\ 45^s$ were required to expand Bx, while only $39^m\ 50^s$ were required to expand hoop Ax, though the relative expansion of the former was less in the proportion of 2.113 + to 2.154.

The absolute expansion, however, of Bx was .0127 inch greater than that of Ax.

The difference in expansion does not account for the difference in time required for heating, nor will the difference in volume of metal to be heated account for it.

This discrepancy may be accounted for by noting that the same heater was used, and, in consequence of the greater circumferential distance between the burners, due to the longer radii of the arms required for Bx, the heating would not be so rapid as in the case of Ax.

Slight variations in gas pressure would also affect the time required for heating. The temperature of Bx, as shown by the color test, was slightly greater than that of the inner hoop.

The best method of heating the hoops would undoubtedly be to place them centrally on a spider in a horizontal position and allow hot air to enter the heater axially, strike a flat cover (which is movable), and flow outward and downward, enveloping the hoop in such a way as to heat all parts of it uniformly. The exit pipes could be arranged around the bottom near the perimeter of the heater. In this method the temperature of the interior of the heater could be definitely ascertained with tolerable accuracy and the temperature of the hoop kept within any fixed maximum limit, not exceeding 600° Fahrenheit.

With the gas heater, although a slight oscillatory rotary motion is maintained, it is found impossible to keep every segment of the circumference of the hoop at the same temperature. Some segments—generally those at the top and bottom, on account of the upward current of air induced by the heat—will have a higher temperature than others. Yet, on the whole, very good results may be obtained with reasonable care.

With a reverberatory furnace the same difficulty—*i. e.*, that of unequal heating—will be encountered.

In such a furnace the heat is necessarily variable at different points, due to the form of the furnace arch and the existence of a bridge wall. The most favorable case with such a furnace would be to have a horizontal rotary hearth, upon which the hoop is laid flat on two or more cross-bars so that the segment of the perimeter farthest from the bridge wall should occupy the point of maximum heat, and then by slow and uniform rotation of the hearth every point of the circumference would be carried consecutively through the zone of greatest heat. The hoop would have to be roughly centered over the pivot of the rotating hearth.

The bars are laid on the hearth in order to expose as much of the hoop surface as possible to the action of the heated air and flame. Even with this contrivance it is doubtful whether the heating would be as uniform as with a good gas-heater, unexposed to drafts, and under a steady gas pressure. The furnace has the advantage of keeping the hoop horizontal, hence there is no sagging due to the weight of the hoop, or compression due to the method of slinging used for the gas heater.

With large hoops it is found that the expansion rod may enter horizontally before it will vertically, or *vice versa*, depending upon the weight and method of slinging. If a furnace is to be used, it would probably be preferable to employ a large muffle furnace similar to those used for roasting arsenical ores when the arsenious acid is to be saved and collected as a by-product. With such a furnace no flame would come in contact with the hoops and the operator would be better able to judge of the temperature of his furnace by inspection since no glare of flame would enter as a perturbatory factor to mask the color of the oxide upon the steel surface. The furnace operator could also regulate the heat of his muffle by having at hand a little charcoal to place at points inside the muffle which are cooling, or are colder than he desires. Of course careful firing would be required, but not nearly so much care would be necessary as in the case of an ordinary reverberatory furnace, since the degree of heat can be regulated by opening the doors of the muffle, if too great, and by urging the fire or putting charcoal in the muffle, if too low.

Any one of the three latter methods is to be preferred to the uncertainty and irregularity of the old method of heating in a perforated flask with a wood fire.

COLOR TEST.

The color test for temperature and approximate degree of expansion has been as satisfactory in this experimental cylinder as with the hooping of the 12-inch M. L. mortar. The limit of *dark brown* has been adhered to as indicating the highest temperature to be attained in heating, and all necessary expansion can be obtained without going beyond that limit with the quality of steel now furnished by the Midvale Steel Cympany for the Army and Navy work at this foundry.

The 6-inch Navy guns assembled at this foundry afforded an excellent opportunity, both in the hooping and in the shrinking on of the jackets, to observe the correspondence of color with the degree of expansion required.

The five Navy guns already assembled made a series of fifty hoops available for observations on this point.

The Navy Department use a greater expansion, and, consequently, a little higher heat than employed by the Ordnance Department at this place upon the same quality of work, yet with their greater heat they rarely exceed the color of *dark brown*.

The Navy hoops were made of steel by the same company, were heated in the same heater, and under the same conditions as regards light, draughts, &c., as were the Army hoops, so that the color tests were observed under the same conditions in both instances, and hence are directly comparable.

RESULTS.

The numerical results of the experiments are given in Tables 1, 2, and 3, appended hereto.

The tables of detailed measurements are placed in the Appendix.

The measurements in these tables were made by Lieut. H. D. Borup, Ordnance Department, U. S. A.

TABLE 1.—*Temperature of water in bore during hooping.*

[Flow of water through bore = 9 gallons per minute during application of cast-iron body; 7.8 gallons per minute during application of hoop A*x*; 9 gallons per minute during application of hoop B*x*.]

Hoop.	Temperature of water in bore.					Time after hoops in position.			Duration of—		
						Before.					
	Hydrant.	At instant hoop put on.	Maximum temperature.	Extreme range of.	When hoop cold.	Change of temperature noted.	Temperature normal again.	Observations taken.	Rise of temperature.	Maximum temperature.	Decrease of temperature.
	°*F.*	°*F.*	°*F.*	°*F.*	°*F.*	*m.*	*h. m. s.*	*h. m. s.*	*m.*	*m.*	*h. m.*
Cast-iron body	55	55	59	4	55	3.5	5 27 30	5 42 30	8	14	5 02
Hoop A*x*	60	60	62	2	60	17	42	59	12	12	19
Hoop B*x*	62	62	63.5	1.5	62	19.66	52	72	15	15	22

TABLE 2.—*Diameters, compressions, and extensions of bore of experimental cylinders from 12-inch hooped and tubed B. L. rifle, as affected by hooping.*

[Table showing diameters of bore of steel tube section of experimental cylinder—before hooping; after application of cast-iron body, Hoops A*x* and B*x*; after finishing exterior of cast-iron body, Hoops A*x* and B*x*; after finish-boring; also the compressions of the bore due to the application of cast-iron body, Hoops A*x*, and B*x*, and all three; together with the extensions of the bore due to finishing, the exterior of cast-iron body, Hoops A*x*, and B*x*, and all three.]

Distance from marked face.	Diameters of bore ready for hooping, &c.							Compression of bore due to—				Extension of bore due to—			
	Steel tube before hooping. (a)	After application of cast-iron body. (b)	After finishing exterior cast-iron body. (c)	After application of Hoop A*x*. (d)	After finishing exterior of Hoop A*x*. (e)	After application of Hoop B*x*. (f)	After finishing exterior of Hoop B*x*.*	Application of cast-iron body. (a—b)	Application of Hoop A*x*. (c—d)	Application of Hoop B*x*. (e—f)	Application of all three. (a—f)	Finishing of exterior of cast-iron cylinder. (h=c—b)	Finishing of exterior of Hoop A*x*. (k=e—d)	Finishing of exterior of Hoop B*x*.*	Total due to all three. (h+k)
	Inches.	*Inches.*	*Inches.*	*Inches.*	*Inches.*	*Inches.*	*Inches.*	*Inches.*	*Inches.*	*Inches.*	*Inches.*	*Inches.*	*Inches.*	*Inches.*	*Inches.*
0.1 inch	13.5004	13.4986	13.4982	13.4906+	13.4904	13.4836+	....	.0018	.0076	.0068	.0168(—)	—.0004	—.0002	....	—.0006
1 inch	13.5003	13.4981	13.4980	13.4906+	13.4903	13.4832+	....	.0522	.0074	.0071	.0171(—)	—.0001	—.0003	....	—.0004
2 inches	13.5005	13.4981	13.4981+	13.4903+	13.4900	13.4832+	....	.0024	.0078	.0068	.0173	+.0000+	—.0003	....	—.0003—
3 inches	13.5005	13.4981	13.4980	13.4903+	13.4903	13.4832+	....	.0624	.0077	.0071	.0173	—.0001	.0000	....	—.0001
4 inches	13.5005	13.4980	13.4981+	13.4906+	13.4900	13.4832+	....	.0025	.0075	.0068	.0173	+.0001	—.0006	....	—.0005
5 inches	13.5009	13.4980	13.4980	13.4903	13.4899	13.4832+	....	.0029	.0077	.0067	.0177	.0000	—.0004	....	—.0004
6 inches	13.5008	13.4980	13.4980	13.4903	13.4899	13.4830	....	.0028	.0077	.0069	.0178	.0000	—.0004	....	—.0004
7 inches	13.5009	13.4980	13.4980	13.4903	13.4896	13.4825	....	.0029	.0077	.0071	.0184	.0000	—.0007	....	—.0007
8 inches	13.5006	13.4980	13.4980	13.4902	13.4896	13.4820	....	.0026	.0078	.0076	.0186	.0000	—.0006	....	—.0006
9 inches	13.5005	13.4981	13.4980	13.4898	13.4891+	13.4820	....	.0024	.0082	.0071	.0185	—.0001	—.0007	....	—.0008
9.4 inches	13.5006	13.4981	13.4981+	13.4898	13.4890	13.4816+	....	.0025	.0083	.0074	.0190	+.0000+	—.0008	....	—.0008
Means	13.5096	13.4981	13.4980	13.4903	13.4898	13.4828+	....	.0025	.0077	.0070	.0178	—.0001	—.0005	....	—.0006

*Hoop finished before application.

SUMMARY.

Mean values.

Compression due to application of cast-iron body $=(a-b)=.0025$.
Compression due to the application of Hoop A*x*. $=(c-d)=.0077$.
Compression due to application of Hoop B*x*. $=(e-f)=.0070$.
Total $=m=(a-b)+(c-d)+(e-f)=.0172$.
†Elongation due to finishing exterior cast-iron body $=h=c-b=-.0001$.
Elongation due to finishing exterior A*x* $k=e-d=-.0005$.
Total $=h+k=-.0006$.
Subtracting total elongation from total compression we have the resulting compression $=C=m+(h+k)=.0172-(-.0006)=.0178$.
Subtracting compressions derived directly from mean diameters $=a-f_x$. .0178—, which corresponds with the value above obtained.

†The elongations being negative show that they are compressions. The negative results are probably due to errors of observation, and are within the limits of accurate work.

TABLE 3.—*Summary of results obtained in hooping experiments for 12-inch hooped and tubed breech-loading rifle.*

Stages when measured.	Mean diameter.								Mean length.*			
	Tube.		Cast-iron body.		A hoop.		B hoop.		Tube. Interior.	Cast-iron body. Exterior.	A-hoop. Exterior.	B-hoop. Exterior.
	Interior.	Exterior.	Interior.	Exterior.	Interior.	Exterior.	Interior.	Exterior.				
	Inches.	*Inches.*	*Inches.*	*Inches.*	*Inches.*	*Inches.*	*Inches.*	*Inches.*	*Inches.*	*Inches.*	*Inches.*	*In.*
Prepared for application of cast-iron body	13.5006	20.00535+	19.9993	39.3532	......	......	......	......	9.496	9.49975	......	......
With cast-iron body applied	13.4981	20.005	20.0050	39.3568	......	......	......	......	9.495	9.49987	......	......
Prepared for application of A hoop	13.4980+	20.0051	20.0051+	39.2654	39.2007	46.0168+	......	......	9.495	9.5002	8.999	......
With A hoop applied	13.4903+	19.9966+	19.9966+	39.2569	39.2569	46.0671+	......	......	9.496	......	8.996	......
Prepared for application of B hoop	13.4898+	19.9973−	19.9973−	39.2568+	39.2568+	45.9767+	45.9000+	53.6963	9.495	......	8.996	9.000
With cast-iron body and A and B hoops applied	13.4828+	19.989	19.989	39.2473	39.2473+	45.968	45.968	53.7569−	9.4973−	......	......	8.9978
After removal of B hoop	13.4894+	19.9965	19.9965	39.2571+	39.2571+	45.9758+	45.9591	53.7537+	9.495	......	8.9937+	9.000
After removal of A hoop	13.4959+	20.0031+	20.0031+	39.2635+	39.2469+	45.9638+	......	......	9.4941+	9.4982+	8.9992+	......
After removal of casting	13.4996+	20.0044+	20.0019+	39.2643+	......	......	......	......	9.4938+	9.4992	......	......

Linear and proportional differences.	Inches.	Thousandths per linear inch.	Inches.	Thousandths per linear inch.	Inches.	Thousandths per linear inch.	Inches.	Thousandths per linear inch.	Inches.	Thousandths per linear inch.	Inches.	Thousandths per linear inch.	Inches.	Thousandths per linear inch.	Inches.	Thousandths per linear inch.
Theoretical shrinkages	......	......	.005	0.25	......	......	.0686	1.75	......	......	.0739	1.611	......	......	......	......
Prescribed shrinkages:																
Maximum	......	......	.0056	.283	......	......	.07069	1.788	......	......	.0754	1.644	......	......	......	......
Minimum	......	......	.0036	.183	......	......	.06707	1.711	......	......	.0724	1.578	......	......	......	......
Actual shrinkages	......	......	.00605	.302+	......	......	.0647	1.650+	......	......	.0767+	1.671+	......	......	......	......
Compression of tube after application of jacket	0.0025	0.185	.00035	.017+	......	......	......	......	......	......	......	......	......	......	......	......
Elongation of jacket after application	......	......	......	......	.0057	0.285	.0036	0.091+	......	......	......	......	......	......	......	......
Compression of tube and cast-iron body by A hoop	.0077	0.570+	.0085	0.424+	.0085	0.424+	.0085	0.216+	......	......	......	......	......	......	......	......
Elongation of A hoop after application	......	......	......	......	......	......	......	......	.0562	1.433+	.0503	1.093	......	......	......	......

* There was virtually no change in length that could be detected by measurement. The errors of observation and the removal of unavoidable burs from the edges near the points of measurement are sufficient to account for all the variations noted in the table.

Compression of tube, cast-iron body, and A hoop by B hoop	.007	0.518+	.0083	0.415	.0083	.0415+	.0095	0.242+	.0095	0.242+	.0087	0.189+	....	....	....	....
Elongation of B hoop after application	....	....	....	....	....	....	....	....	....	....	....	....	.068	1.481	.0696	1.128+
Total compression of tube and cast-iron body by A and B hoops	.0152	1.126	.0161	.8048	.0161	0.8048	.0181	0.461	....	....	....	....	....	....	....	....
Restoration of tube, cast-iron body, and A hoop after removal of B hoop	.0066	0.4895+	.0075	0.3752	.0075	0.3752	.0098	0.2497	.0098	0.2497	.0078	0.1697	....	....	....	....
Restoration of tube and cast-iron body after removal of A hoop	.0065	0.4819	.0066	.330+	.0066	0.330+	.0064	0.163+	....	....	....	....	....	....	....	....
Restoration of tube after removal of cast-iron body	.0037	0.2741+	.0013	0.0649+	....	....	....	....	....	....	....	....	....	....	....	....
Total restoration of tube and cast-iron body	.0168	1.246	.0154	0.7704	....	....	....	....	....	....	....	....	....	....	....	....
Permanent compression	.001	0.0740+	.00095	0.0474+	....	....	....	....	....	....	....	....	....	....	....	....

Effects of hooping and unhooping upon the mean lengths of the tube, cast-iron body, and hoops A and B.

Stages when measured.	Mean lengths interior.	Actual compression.	Actual elongation.
(1) *Section of steel tube.*			
Prepared for application of cast-iron body	9.496		
With cast-iron body applied	9.495	.001	
Prepared for application of A hoop	9.495	.000	[illegible]
With A hoop applied	9.496		[illegible]
Prepared for application of B hoop	9.495	.001	
With cast-iron body and A and B hoops applied	9.4973		[illegible]
After removal of B hoop	9.495	.0023	
After removal of A hoop	9.4941+	.0009	
After removal of cast-iron body	9.4938+	.0003	
Totals		.0055	[illegible]
Permanent compression		.0022	

Stages when measured.	Mean lengths exterior.	Actual compression.	Actual elongation.
(2) *Cast-iron body.*			
Prepared for application	9.49975		
Applied to tube	9.49987		[illegible]
Prepared for application of A hoop	9.5002		[illegible]
After removal of A hoop	9.4982	.002	
After removal from tube	9.4992		[illegible]
Totals		.002	[illegible]
Permanent compression		.00055	
(3) *A hoop.*			
Prepared for application	8.999		
Applied to cast-iron body	8.996	.003	
Prepared for application of B hoop	8.996	.0	.0
After removal of B hoop	8.9937+	.0023	
After removal from cast-iron body	8.9992+		[illegible]
Totals		.0053	[illegible]
Permanent elongation			[illegible]
(4) *B hoop.*			
Prepared for application	9.		
After application	8.9978−	.0022	
After removal	9.		[illegible]
Totals		.0022	[illegible]
Permanent elongation or compression		.0	.0

SUMMARY.*

	Permanent compression.	Permanent elongation.
Steel tube	.0022	
Cast-iron body	.00055	
Hoop A*x*		[illegible]
Hoop B*x*	.0	.0

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* There was virtually no change in length that could be detected by measurement. The [illegible] observation and the removal of unavoidable burs from the edges near the points of [illegible] sufficient to account for all the variations noted in the table.

Comparison tests (radial and tangential)—cast-iron body for 12-inch B. L. rifle—hooped and tubed with steel—before and after hooping experiments.

BREECH RING.

[Tangential test specimens, 12 inches long and 1.129 inches in diameter.]

Marks.	.00045	.00050	.00055	.00060	.00065	.00070	.00075	.00080	.00085	.00090	.00095	.00100	.00105	.00110	.00115	.00120	.00125	Ultimate strength.	Compression per inch prior to breaking.
B. R. 3, outside:																			
Before	9, 750	10, 750	11, 750	12, 750	13, 750	14, 750	15, 750	16, 500	17, 500	18, 250	18, 750	19, 250	20, 250	20, 750	21, 500	22, 500	23, 250	52, 080	.014
After	10, 500	11, 500	12, 500	13, 500	14, 500	15, 500	16, 500	17, 250	18, 000	19, 000	19, 750	20, 500	21, 500	22, 250	23. 000	23, 500	24, 250	51, 450	.0059
B. R. 4, inside:																			
Before	9, 500	10, 500	11, 500	12, 500	13, 250	13, 750	14, 750	15, 750	16, 500	17, 250	18, 000	18, 750	19, 250	20, 250	20. 750	21, 500	22, 500	50, 000	.018
After	9, 900	11, 900	12, 900	13, 900	14, 900	15, 900	16, 900	17, 900	18, 750	19, 500	20, 250	21, 000	21, 750	22, 500	23, 250	23, 750	24, 500	49, 900	.00638
B. R. 5, inside:																			
Before	9, 500	10, 500	11, 250	11, 750	12, 750	13, 750	14, 500	15, 500	16, 500	17, 250	17, 750	18, 500	19, 250	20, 000	20, 500	21, 500	22, 250	48, 660	.016
After	10, 500	11, 500	12, 750	13, 500	14, 500	15, 500	16, 500	17, 500	18, 500	19, 500	20, 250	20, 900	21, 750	22, 500	23, 500	24, 250	24, 500	51, 100	.00580

[Radial test specimens, 9 inches long and 1.129 inches in diameter.]

Marks.	.00045	.00050	.00055	.00060	.00065	.00070	.00075	.00080	.00085	.00090	.00095	.00100	.00105	.00110	.00115	.00120	.00125	Ultimate strength.	Compression per inch prior to breaking.
B. R. 7, before	9, 500	10, 500	11, 500	12, 500	13, 500	14, 500	15, 250	16, 000	17, 250	18, 000	18, 750	19, 500	20, 250	21, 250	21, 750	22, 500	23, 000	50, 490	.018
No. 6, after	10, 500	11, 500	12, 750	13, 750	14,750	15, 500	16, 500	17, 250	17, 750	19, 000	19, 750	20, 500	21, 000	21, 750	22, 750	23, 500	24, 000	64, 300	.00622
B. R. 8, before	9, 500	10, 500	11, 500	13, 750	13, 750	14, 500	15, 250	16, 000	17, 250	17, 750	18, 750	19, 500	20, 250	21, 000	21, 500	22, 500	23, 250	......	....
No. 7, after	10, 000	11, 500	12, 250	13, 000	14, 000	15, 250	15, 800	16, 500	17, 500	18, 500	19, 250	20, 000	21, 000	21, 500	22, 800	23, 250	23, 750	66, 900	.00598

Tensile tests—Whitworth steel tube for 12-inch B. L. rifle—hooped and tubed—before and after hooping experiments.

[Tangential specimens 3 inches in length and .25 square inch cross-section.]

Marks on specimens.	25,000	30,000	35,000	40,000	45,000	50,000	55,000	60,000	65,000	70,000	75,000	80,000	85,000	90,000	Elastic limit.	Elongation per inch at elastic limit.	Ultimate strength.	Elongation per inch after rupture.	Reduction in area after rupture.	Specific gravity.	Hardness.
															Lbs.	*Inches.*	*Lbs.*	*Per cent.*	*Per cent.*		
12-inch H. & T., 1, outside:																					
Before	.000733	.000933	.001100	.00123	.001433	.00163	.01000	.01336	.01893	.0233	.03106	.03806	.05250	.06806	54,000	.00180	94,720	21.67	39.2	7.8658	18.09
After	.000867	.001033	.001200	.001367	.001533	.001700	.00933	.01193	.01700	.02167	.02893	.0353	.0484	.06216	52,000	.001767	96,400	20.33	39.2	......	....
12-inch H. & T., 2, inside:																					
Before	.000800	.000967	.001133	.001267	.00140	.00163	.001767	.001833	.01133	.01433	.01950	.0236	.03153	.03833	56,000	.00183	101,880	11.0	21.4	......	....
After*	.000833	.001033	.001167	.001333	.001583	.006767	.009767	.01397	.02003	.02506	.03373	.04186	.05930	.0867	48,000	.001633	91,800	10.33	11.8	......	....
12-inch H. & T., 3, middle:																					
Before	.000833	.00100	.001167	.001333	.00150	.001767	.010200	.01430	.0200	.02506	.0342	.0423	.0612	.0867	50,000	.001767	92,200	19.67	27.6	7.8667	16.81
After	.000833	.00100	.001167	.001400	.001600	.007833	.01079	.01536	02167	.02673	.03633	.04470	.0647	.0967	48,000	.001733	92,800	22.0	41.9	......	....

[Radial specimens 2 inches in length and .25 square inch cross-section.]

Marks on specimens.	25,000	30,000	35,000	40,000	45,000	50,000	55,000	60,000	65,000	70,000	75,000	80,000	85,000	90,000	Elastic limit.	Elongation per inch at elastic limit.	Ultimate strength.	Elongation per inch after rupture.	Reduction in area after rupture.	Specific gravity.	Hardness.
12-inch H. & T., 4, before	.000650	.000850	.001000	.001200	.013600	.006700	.010000	.014150	.019750	.024750	.033000	.040600	.058250	.077500	41,000	.001250	91,520	10.50	15.0	......	....
12-inch H. & T., 5, before	.000700	.000950	.001050	.001350	.003550	.006400	.009700	.013050	.018800	.023350	.031100	.038500	.055000	.075000	41,000	.001450	92,480	12.50	21.4	......	....

Compression tests—Whitworth steel tube for 12-inch B. L. rifle—hooped and tubed.

[Tangential specimens 5 inches in length and .50 square inch cross-section.]

Marks on specimens.	25,000	30,000	35,000	40,000	45,000	50,000	55,000	60,000	65,000	70,000	75,000	80,000	85,000	90,000	Elastic limit.	Elongation per inch at elastic limit.	Ultimate strength.	Elongation per inch after rupture.	Reduction in area after rupture.	Specific gravity.	Hardness.
12-inch H. & T., 6, outside, 4:																					
Before	.000700	.000867	.001033	.001200	.001367	.001833	.006433	.009067	......	......	......	......	......	......	48,000	.001567	88,620	......	....	......	....
After	.000800	.000950	.001100	.001300	.001400	.00170	.008350	.01150	......	......	......	......	......	......	51,000	.001750	89,700	......	......	......	....
12-inch H. & T., 7, inside, 5:																					
Before	.000700	.000867	.001033	.001167	.001333	.001467	.001800	.007233	......	......	......	......	......	......	54,000	.001567	89,580	......	......	......	....
After	.000850	.000950	.00100	.001200	.001350	.00610	.009150	.01270	......	......	......	......	......	......	46,000	.00140	84,560	......	......	......	....
12-inch H. & T., 8, middle, 6:																					
Before	.000767	.000883	.001100	.001267	.001433	.007500	.010583	.014400	......	......	......	......	......	......	46,000	.001467	83,920	....	......	......	....
After	.000750	.000900	.001150	.001200	.001500	.00680	.009750	.01315	......	......	......	......	......	......	46,000	.001600	84,640	......	......	......	....

[Radial specimens 4.25 inches in length and .50 square inch cross-section.]

12-inch H. & T., 9, before.	.000667	.000833	.001000	.001133	.001333	.001467	.007533	.010533	.... .	......	......	......	......	......	50, 000	.001467	102, 100	......	......	......	....
12-inch H. & T., 10, before.	.000667	.000833	.001000	.001067	.001233	.001400	.005567	.008333	......	......	......	......	......	......	51, 000	.001433	104, 340	......	......	......	....

[Radial specimens 3.22 inches long, .50 square inch.]

12-inch H. & T., 7, after..	.000750	.000900	.001150	.001200	.001350	.001550	.00875	.01200	......	......	......	......	......	......	56, 000	.00155	130, 000	......	......	......	....
12-inch H. & T., 8, after..	.000700	.000850	.001150	.001250	.001500	.00185	.00875	.01215	......	......	......	......	......	......	50, 000	.001850	130, 000	......	......	......	....

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* This specimen was taken between inside and middle.

† This specimen was taken from between middle and inside.

Tensile tests.—Specimens from 12-inch rifle hoops Ax and Bx, both before and after hooping test.

[Specimens 6 inches in length and .25 square inch cross-section.]

Marks on specimens.	Before or after hooping.	Elongations per inch of length caused by the loads per square inch of cross-section.												Elastic limit.	Elongation per inch at elastic limit.	Ultimate strength.	Elongation per inch after rupture.	Reduction in area after rupture.	Specific gravity.	Hardness.
		Load, 30,000 pounds.	Load, 35,500 pounds.	Load, 40,000 pounds.	Load, 45,000 pounds.	Load, 48,000 pounds.	Load, 50,000 pounds.	Load, 52,000 pounds.	Load, 54,000 pounds.	Load, 55,000 pounds.	Load, 60,000 pounds.	Load, 64,000 pounds.	Load, 70,000 pounds.	*Lbs.*	*Inches.*	*Lbs.*	*. c.*	*P. c.*		
12 R Ax, inside, No. 7	Before	.000967	.001133	.001300	.001467	.001567	.001683	.001767	.001933	.002033	.002967	.004583	.008967	52,000	.001767	107,920	12.67	27.6	7.8515	22.39
12 H T A, inside, No. 2	After	.000917	.001083	.001250	.001400	.001500	.001600	.001700	.001800	.001967	.003517	.006083	.011167	53,000	.001733	105,080	14.67	36.4	......	.....
12 R Ax, outside, No. 8	Before	.001017	.001183	.001350	.001533	.001650	.001750	.001867	.002017	.002083	.003017	.004750	.009950	53,000	.001917	106,000	13.17	30.6	......	.....
12 H T A, outside, No. 1	After	.000883	.001000	.001183	.001350	.001467	.001550	.001600	.001733	.001817	.003483	.006167	.011300	53,000	.001650	103,240	13.67	39.2	......	.....
12 R Ax, middle, No. 9	Before	.000967	.001133	.001300	.001467	.001617	.001700	.001850	.002050	.002183	.003500	.005583	.010400	50,000	.001700	106,160	15.50	30.6	......	.....
12 R Ax, middle, No. 10	Before	.000983	.001117	.001300	.001467	.001633	.001783	.002000	.002283	.002433	.004483	.006833	.011833	49,000	.001683	105,600	14.33	30.6	......	.....
12 H T A, middle, No. 3	After	.000917	.001067	.001233	.001367	.001483	.001567	.001667	.001867	.002017	.003467	.006167	.010667	53,000	.001717	105,280	14.67	36.4	......	.....
12 H T A, middle, No. 4	After	.000933	.001100	.001267	.001400	.....	.001600	.001717	.001883	.002017	.003333	.005700	.010600	53,000	.001783	104,680	13.33	39.2	......	.....
12 R Bx, inside, No. 5	Before	.001100	.001283	.001483	.001683	.001817	.001883	.002050	.002667	.003200	.006917	.009833	.014933	51,000	.001950	100,160	13.83	39.2	......	.....
12 H & T B, inside, No. 2	After	.000933	.001117	.001250	.001450	.001550	.001617	.001683	.001800	.001900	.004733	.007500	.012250	53,000	.001783	104,600	15.83	36.4	7.8548	22.14
12 R Bx, outside, No. 6	Before	.001083	.001283	.001450	.001617	.001783	.001850	.001933	.002050	.002200	.004667	.007417	.012217	53,000	.001967	105,120	15.17	33.5	......	.....
12 H & T B, outside, No. 1	After	.000933	.001100	.001283	.001433	.001550	.001617	.001683	.001850	.001933	.004933	.007833	.012750	52,000	.001683	103,520	14.83	39.2	......	....
12 R Bx, middle, No. 1*	Before	.000867	.001067	.001233	.001383	.001483	.001550	.001650	.001750	.001833	.005467	.008000	.012833	54,000	.001750	104,320	13.83	36.4	7.8532	21.52
12 R Bx, middle, No. 2*	Before	.000917	.001083	.001267	.001417	.001533	.001617	.001683	.001800	.002083	.006017	.008500	.013000	53,000	.001717	104,000	12.67	36.4	.....	.....
12 R Bx, middle, No. 3*	Before	.000900	.001067	.001233	.001383	.001500	.001583	.001683	.001800	.002117	.005117	.007500	.011833	54,000	.001800	106,760	14.00	33.5	.....	....
12 R Bx, middle, No. 4*	Before	.000900	.001067	.001233	.001400	.001500	.001600	.001667	.001983	.002433	.005250	.007833	.013000	52,000	.001667	105,280	14.83	36.4	.....	.....
12 H & T B, middle, No. 3*	After	.001000	.001150	.001317	.001467	.001567	.001700	.001900	.003117	.003650	.006700	.009667	.014600	48,000	.001567	102,000	15.50	36.4	......	.....
12 H & T B, middle, No. 4*	After	.000917	.001050	.001250	.001400	.001483	.001600	.001900	.003467	.004233	.007917	.010583	.016333	49,000	.001533	100,400	15.67	39.2	......	.....

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* It is quite probable that the higher qualities of the middle specimens before hooping are due to the fact that they were taken from an outside shell, which would give the middle specimens the benefit of the tempering to a greater degree than if located farther within the hoop.

APPENDIX 29.

ANALYSIS OF EXPERIMENTS MADE ON HOOPING AN EXPERIMENTAL CYLINDER REPRESENTING A SECTION THROUGH POWDER CHAMBER OF 12-INCH BREECH-LOADING RIFLE, HOOPED AND TUBED.

BY LIEUT. ROGERS BIRNIE, JR., ORDNANCE DEPARTMENT.

Summary of results obtained in hooping experiments for 12-inch H. and T. cast-iron breech-loading rifle.

Stages when measured.	Mean diameter.							
	Tube.		Jacket.		A-hoop.		B-hoop.	
	Interior.	Exterior.	Interior.	Exterior.	Interior.	Exterior.	Interior.	Exterior.
	Inches.	*Inches.*	*Inches.*	*Inches.*	*Inches.*	*Inches.*	*Inches.*	*Inches.*
Prepared for application of jacket	13.5006	20.00535	19.9993	39.3532	....	....	....	....
With jacket applied	13.4981	20.005	20.005	39.3568	....	....	....	....
Prepared for application of A-hoop	13.498	20.0051	20.0051	39.2654	39.2007	46.0168	....	....
With A-hoop applied	13.4903	19.9966	19.9966	39.2569	39.2569	46.0671	....	....
Prepared for application of B-hoop	13.4898	19.9973	19.9973	39.2568	39.2568	45.9767	45.9000	53.6963
With jacket and A and B hoops applied	13.4828	19.989	19.989	39.2478	39.2478	45.9680	45.9680	53.7569
After removal of B-hoop	13.4894	19.9965	19.9965	39.2571	39.2571	45.9758	[45.9591]	[53.7537]
After removal of A-hoop	13.4959	20.0031	20.0031	39.2635	[39.2469]	[45.9638]	....	....
After removal of jacket	13.4996	20.0044	[20.0019]	[39.2643]	....	....	....	....

Linear and proportional differences.	Tube. Interior. Inches.	Tube. Interior. Thousandths per linear inch.	Tube. Exterior. Inches.	Tube. Exterior. Thousandths per linear inch.	Jacket. Interior. Inches.	Jacket. Interior. Thousandths per linear inch.	Jacket. Exterior. Inches.	Jacket. Exterior. Thousandths per linear inch.	A-hoop. Interior. Inches.	A-hoop. Interior. Thousandths per linear inch.	A-hoop. Exterior. Inches.	A-hoop. Exterior. Thousandths per linear inch.	B-hoop. Interior. Inches.	B-hoop. Interior. Thousandths per linear inch.	B-hoop. Exterior. Inches.	B-hoop. Exterior. Thousandths per linear inch.
Theoretical shrinkages	....	......	.005	0.25	....	......	.0686	1.75	....	......	.0739	1.611	....	......	....	......
Prescribed shrinkages:																
Maximum	....	......	.0056	0.280	....	......	.07009	1.788	....	......	.0754	1.644	....	......	....	......
Minimum	....	......	.0036	0.180	....	......	.06707	1.711	....	......	.0724	1.578	....	......	....	......
Actual shrinkages	....	......	.00605	+0.302	....	......	.0647	1.650	....	......	.0767	1.671	....	......	....	......
Compression of tube after application of jacket	—.0025	......	—.00035	......	....	......	....	......	....	......	....	......	....	......	....	......

Elongation of jacket after application					+.0058		+.0036									
Compression of tube and jacket by A-hoop	−.0082		−.0078		−.0078		−.0086									
Elongation of A-hoop after application									*a*+.0561		*a*+.0503					
Compression of tube, jacket, and A-hoop by B-hoop	−.0070		−.0083		−.0083		−.0095		−.0095		−.0087					
Final compression of tube and jacket—an elongation of A and B hoops	*b*−.0178		*b*−.01635		*b*−.0103		*b*−.0145		*c*+.0466		*c*+.0416		*ac*+.0680		*ac*+.0606	
Restoration of tube, jacket, and A-hoop after removal of B-hoop	+.0066		+.0075		+.0075		+.0098		+.0098		+.0078					
Partial set	−.0004		−.0008		−.0008		+.0003		+.0003		−.0009					
Restoration of tube, jacket, and A-hoop on removal of A-hoop	+.0065		+.0066		+.0066		+.0064									
Partial set	−.0017		−.0012		−.0012		−.0022									
Aggregate set	−.0021		−.0020		−.0020		−.0019									
Restoration of tube after removal of jacket	+.0037		+.0013													
Total restoration of tube and jacket	+.0168		+.0154													
Permanent compression	−.001		−.00095													

a Maximum elongation in structure. *b* Maximum and final compression in structure. *c* Final elongation in structure.

Remarks.—The relatively large aggregate "set" of tube shown after removal of A-hoop indicates that the cast-iron body was so compressed by the hoops that its original elastic properties were impaired (or perhaps only changed), and the mass of this metal around the tube was so great that the tube also was prevented from the elastic return which it would have shown except for the abnormal contractile effect of the cast-iron body.

Referring to the accompanying table, giving a comparison of actual with theoretical changes of dimensions incident to the assemblage of the system, we find the results of the experiments as a whole to be very satisfactory and to confirm the accuracy of the formulas. The theoretical values indicate that the modulus of the tube metal has been taken a little too high and the modulii of the hoops too low, although the differences noted may be partly explained by considering the yielding nature of the cast iron. This comparison also shows that the experiment was carefully conducted and that the measurements were skillfully made. However, as regards the length measurements and the diametrical measurements of the two hoops and cast-iron body after removal, they appear, from causes not apparent here, to be unsuitable for such delicate comparisons as we would wish to institute.

ASSEMBLAGE OF COMPOUND CLYINDER—SECTION OF HOOPED AND TUBED 12-INCH CAST-IRON RIFLE OVER CHAMBER—COMPARISON OF MEASURED CHANGES OF DIMENSIONS WITH THEORETICAL.

Original dimensions of elementary cylinders for reference.

Cylinders.	Diameters.		Lengths.
	Interior.	Exterior.	
	Inches.	*Inches.*	*Inches.*
Tube	13.5006	20.00535	9.496
Cast-iron body	19.9993	39.2654	9.49975
A hoop	39.2007	45.9767	8.999
B hoop	45.9000	53.6963	9.000

Values of the actual shrinkage employed.

	Inches.	Thousandths per linear unit.
Cast-iron body	0.00605	0.3025
A hoop	0.0647	1.65051
B hoop	0.0767	1.67102

Table of changes from original dimensions.

Stages of construction. Measurements.	Theoretical.	Actual.	Theoretical.	Actual.	Differences actual from theoretical.	E_1= 8500 tons. Theoretical.	
First stage—Assemblage of jacket.							
Measurements of diameters:	*Inch.*	*Inch.*	(*)	(*)	(*)	*Inch.*	*Thous.*
Bore of tube	−.00242	−.0026	−0.1792	−0.19250	+.0134	[illegible]	[illegible]
Exterior of tube	−.00202	−.0025	−0.10116	−0.125	+.0238	−.0021	[illegible]
Interior of jacket	+.00403	+.0058	+0.20134	+0.290	+.0887	[illegible]	[illegible]
Exterior of jacket	+.00241	+.0036	+0.06151	+0.06148	r.0000	[illegible]	[illegible]
Second stage—Assemblage of A hoop.							
Measurements of diameters:							
Bore of tube	−.00974	−.0108	−0.7215	−0.8000	+.0785	[illegible]	[illegible]
Exterior of tube	−.00814	−.00805	−0.40728	−0.4025	−.0048	[illegible]	[illegible]
Interior of jacket	−.00209	−.002	−0.10478	−0.1000	−.0048	[illegible]	[illegible]
Exterior of jacket	−.00494	−.005	−0.12606	−0.12755	+.0015	[illegible]	[illegible]
Interior of A hoop	+.05735	+.0561	+1.46294	+1.4312	−.0317	+.0576	[illegible]
Exterior of A hoop	+.05178	+.0503	+1.1281	+1.09391	−.0351	+.0521	[illegible]
Third (final) stage—Assemblage of B hoop.							
Measurements of diameters:							
Bore of tube	−.0168	−.0178	−1.2441	−1.3185	+.0744		
Exterior of tube	−.01404	−.01635	−0.702325	−0.8175	+.1152		
Interior of jacket	−.008	−.0103	−0.39982	−0.515	+.1153		
Exterior of jacket	−.01203	−.0145	−0.30684	−0.[illegible]	+.0631		
Interior of A hoop	+.05026	+.0466	+1.28215	+1.1888	−.0933		
Exterior of A hoop	+.04448	+.0416	+0.969	+0.9063	−.0627		
Interior of B hoop	+.0694	+.0680	+1.5119	+1.4815	−.0304		
Exterior of B hoop	+.0627	+.0606	+1.1675	+1.1266	−.[illegible]		

* Thousandths per linear unit.

NOTE.—The theoretical changes of dimensions are computed from the values of actual shrinkages employed, as given above, with the following values for constants—viz: $R_0 = 6.75$, $R_1 = 10.$, $R_2 = 19.6$, $R_3 = 22.95$, $R_4 = 26.85$, $E_0 = 14333.$, $E_1 = 8000.$, $E_2 = E_3 = 12941.$

N. B.—The two columns at right of page give theoretical changes for $E_1 = 8500$ tons.

APPENDIX 30.

REPORT ON AN EXPERIMENT TO DETERMINE THE EFFECT OF POURING MOLTEN CAST IRON ABOUT A PIECE OF OIL-TEMPERED STEEL.

BY LIEUT. F. E. HOBBS, ORDNANCE DEPARTMENT.

(1 plate.)

MIDVALE STEEL WORKS,
Philadelphia, Pa., July 24, 1885.

The CHIEF of ORDNANCE, *U. S. A.*,
Washington, D. C.:

SIR: I have the honor to report that, in compliance with your instructions and authority of July 8, I have made an experiment to determine the effect of pouring molten cast iron about a piece of oil-tempered steel.

The metal selected was from the muzzle end of tube No. 15 for 8-inch converted rifles, which had been rejected on account of poor tests from the breech end, a piece 15 inches long being cut from the muzzle end for the purpose. A light finishing cut, about 2 inches in length, was taken on the bore of this piece, at the end from which test specimens had been taken.

As no accurate calipers for making fine measurements were at hand, a gauge-rod was made to accurately fit this finished bore, measurements being taken at two scored diameters at right angles to each other. As it was desired that the expansion of this piece of tube due to the heating of the molten cast iron should be at least .02 inch on the diameter, another gauge rod was made .02 inch longer than the first one, to be used to determine when the piece of tube with the molten cast iron about it had expanded that amount.

The weight of cast iron to be used was determined from a consideration of the specific heats of the two metals, the weight of the piece of tube, and the melting point of cast iron, with a view to obtaining a temperature of not over 600° Fahrenheit in the steel, under the supposition that the two metals could be intimately mixed. Of course the supposition was not strictly correct, as there was only contact of the two metals, and the surface of contact in the steel was liable to be heated to a much higher temperature than 600°; but it was hoped by removing the cast iron as soon as possible that the steel would not be raised to an excessively high temperature, and it was deemed best to make a calculation under a supposition that would give a definite empirical rule that could be followed in any subsequent similar heating operation.

The amount of cast iron required was found to be about 120 pounds, giving a thickness of about .8-inch of metal about the piece of tube.

The piece of tube was placed with its axis vertical in a green-sand mold, and was sunk about one inch in the lower flask of the mold to prevent the molten metal from running under the bottom, and so up into the bore. Two flat bars of steel, .25-inch thick, were placed vertically in the mold, in the space to be filled with cast iron, and opposite to each other, to facilitate stripping when the desired expansion had been obtained, the runner being separated into two branches at the bottom, so that the metal could enter on either side of one of the flat bars.

To provide for the filling of the mold exactly to the top of the piece of tube and no higher, an overflow for the metal was cut in the mold, its bottom being on a level with the top of the piece of tube; and to further guard against any metal running over the top of the tube, clay was placed around the outside edge of the top end. After the piece of tube had been set in the mold, and everything was in readiness for pouring the cast iron, a final measurement with the gauge-rod was made at the scored diameters to determine that the measurements previously taken were correct.

The cast iron was melted in crucibles, drawn as soon as melted, poured into a hand ladle, carried to the mold, and allowed to stand for a few moments, so that it was quite as cold as it could have well been poured. The mold was filled in one-half minute. As soon as the mold was full, and as rapidly as possible thereafter, measurements were taken with the gauge-rod .02 inch longer than the original diameter, the measurements alternating on the scored diameters. There was no apparent expansion until the heat had progressed through the wall of the tube, when expansion took place very suddenly and sufficiently. Verifying insertions of the longer gauge-rod were immediately made on each scored diameter, the flask lifted, and the cast iron stripped from the tube. The expansion did not take place until two minutes after the mold was full. The piece of tube was entirely free from the hot cast iron in one and a half minutes after the expansion took place. The cast iron had solidified. The metal of the tube showed a black red color, an observation being taken as soon as possible; but this color may have been only apparent, and due to the reflection from the hot cast iron.

The tube was allowed to cool in the open air, and more careful measurements with the longer gauge-rod than could be taken over the hot cast iron were made at this time. It was found that the longer gauge-rod had a play of about one inch in the bore—*i. e.*, it could be moved back and forth that distance—so that the expansion was a little more than .02 inch.

Measurements taken 25 minutes after the tube was free from the cast iron showed that the tube had not up to that time contracted appreciably. The metal was poured late one evening, and the tube was allowed to stand over night. Measurements on the scored diameters taken the following morning, about 13 hours after the pouring, with the primitive gauge-rod, showed that the tube had, as nearly as could be determined, contracted to its original diameter.

Four specimens were then cut from this end of the tube, their axis being about 1.5 inch from the end, *i. e.*, from the top of the piece of tube as it stood in the mold. The tests of these specimens have shown that the physical qualities of the metal were not changed by the operation. The summary of results of tests of specimens before and after the pouring is as follows:

BEFORE HEATING.

Position of specimen.	Elastic limit.	Elastic elongation.	Tensile strength.	Elongation after rupture.	Contraction of area.
M T$_1$ I	46,000	.001467	81,320	19	49.7
M T$_2$ O	43,000	.001400	81,240	26.33	52.2
M T$_3$ M	40,000	.001333	78,160	23.33	54.6
AFTER HEATING.					
M T$_4$ I	45,000	.001267	78,480	21	54.6
M T$_5$ O	43,000	.001300	80,240	24.33	44.6
M T$_6$ O	40,000	.001333	77,600	19	52.2
M T$_7$ M	43,000	.001367	82,360	21.33	47.2

In conducting a similar heating operation on a large scale special arrangements would undoubtedly have to be made for stripping off the cast iron immediately, the very instant the expansion desired had been obtained.

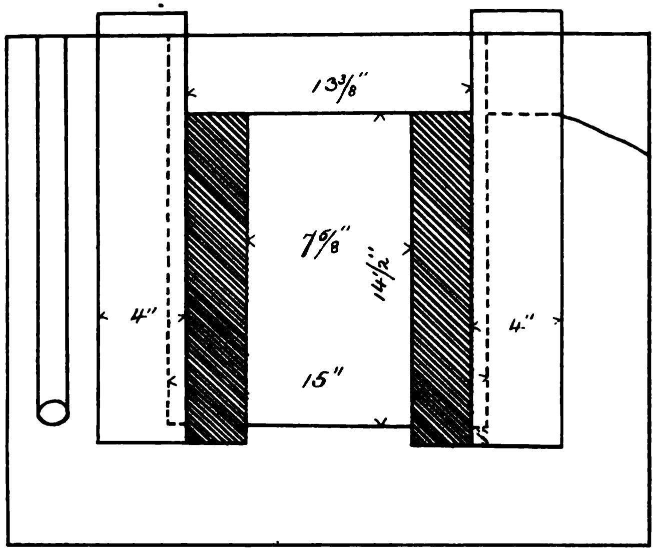
I believe that in this case the metal could have been allowed to remain in contact with the heated cast iron for a considerably longer time without any very great amount of bad effect on the tube metal; but of course sufficient expansion having been obtained, and nothing more being desired, the sooner the cast iron is stripped off the better. The tube metal seemed to hold its heat and remain expanded a sufficiently long time for any desired mechanical operation.

Very respectfully, your obedient servant,

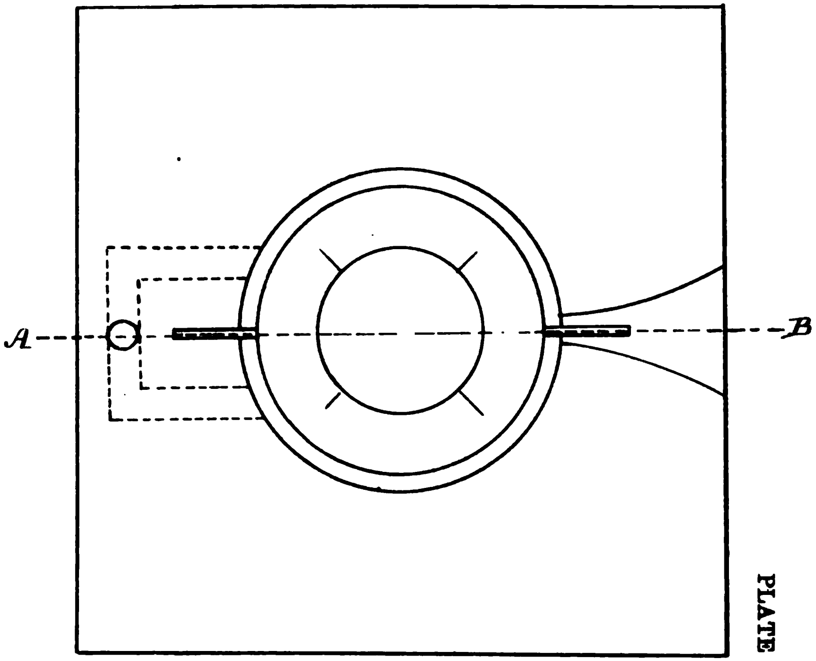
F. E. HOBBS,
Lieut. of Ordnance.

PLATE I.

Sketch showing piece of tube in position to be heated by molten cast iron.



Section on A B



APPENDIX 31.

REPORT ON EXPERIMENTS TO DETERMINE WHETHER THE QUALITY OF TEMPERED STEEL IS INJURED BY BEING SUBJECTED TO VERY HIGH FURNACE HEAT FOR A SHORT TIME.

BY LIEUT. ROGERS BIRNIE, JR., ORDNANCE DEPARTMENT.

(2 plates.)

WEST POINT FOUNDRY,
Cold Spring, N. Y., September 15, 1885.

The CHIEF OF ORDNANCE, U. S. A.,
Washington, D. C.:

GENERAL: In compliance with your instructions dated July 20, 1885, I have the honor to submit the following report of experiments made "to determine the question whether the quality of tempered steel is injured by subjecting the metal to a very high furnace heat for a brief period."

The scope of the experiments was extended to include the removal by the same heat of a tempered-steel cylinder (or hoop) from an interior cylinder upon which it had been assembled with a shrinkage approximately suited to the usages of gun-construction, and from the steel thus treated specimens have been taken from various positions to determine its final qualities, for the purpose of comparison with the qualities of the original metal.

The steel used was a remnant of a cylinder supplied by Sir J. Whitworth & Co., for experimental purposes. One portion of this cylinder had been cut off to test the original qualities of the metal. Another portion was used in constructing the experimental section of the 8-inch breech-loading gun, and was tested subsequent to such use. (See Notes on the Construction of Ordnance, No. 32.) This gives an opportunity to institute an interesting comparison of the qualities of the same metal under three conditions: 1st, its original state; 2d, following its use as an intermediate cylinder of a gun-section and removal therefrom without heat; and 3d, following its use as the outer one of two cylinders shrunk together and subsequent removal by the application of a very high furnace-heat. The parts of the original steel cylinner as used and the positions of the various test specimens are indicated in Plate I. Preliminary to shrinkage the steel cylinder was carefully bored and finished square at the ends. The exterior surface was not disturbed; it was already rough-turned approximately true when received. An old coiled wrought-iron tube, found at the works, was used for the inner cylinder. The breech end of this was prepared to receive the steel cylinder and turned to give a shrinkage of 0.019 of an inch on the diameter of 14.0 inches. The cylinder is shown in place in the sketch, Plate II. The thickness of the wall of steel is 4 inches nearly, and that of the wrought-iron tube 3 inches, being the same proportions as for similar parts of the experimental 8-inch steel gun (double hooped). The stated shrinkage is a little greater than the greatest shrinkage applied in the length of the jacket of that gun on the tube. Measurements were made of a number of original diameters and lengths of the cylinders before its assemblage, to compare with similar measurements to be made after its removal in order to determine the deformation under intermediate operations.

The cylinder was heated for the assemblage in a furnace recently constructed at this foundry for this class of work, in which the metal is heated by hot air alone. The fire was lighted at 8:15 a. m. At 11 a. m. the cylinder was put in. After one hour and thirty minutes the interior diameter was found to have expanded 0.025 of an inch; thirty minutes later the expansion reached 0.035 of an inch, and ten minutes later 0.037 of an inch. It was then removed and placed upon the tube. In this operation the tube was laid on trestles in a horizontal position. The heated cylinder was encircled by a band with a loop at top. It was lifted by a crane, swung around to the tube, and guided to place by hand. The clearance in the assemblage was a little less than 0.02 of an inch on the diameter. The temperature of the steel, judged by its expansion, which was even throughout, was 485° Fahrenheit nearly.* Incidentally an opportunity was here afforded to test the practicability of making a close joint between gun hoops of the same row by simple means. As soon as the cylinder was in place it was drawn close against the shoulder on the tube by means of a cross-piece placed against the outer end and operated by a nut working on a rod passed through the bore of the tube. The extremity of the cylinder next the shoulder was cooled with a circular sprinkler throwing jets of water for fifteen minutes. Afterwards the whole of the cylinder was cooled to make an even temperature. The joint thus obtained was as close as could be desired.

Eighteen days afterwards the cylinder was removed from shrinkage by exposing its outer surface in a furnace already white hot. During the operation the blast was directed above the cylinder and prevented from direct impact by solid brick walls on either side raised from the floor of the furnace to a sufficient height. A sketch of the apparatus used in connection with the furnace heat in effecting the removal is shown, Plate II. Bolted to the muzzle face of the steel cylinder are two thin cast-iron cylinders, which together extend back 8½ feet, and are there connected with a large nut working on a thread cut upon the tube. One of these cylinders has flanges, and the frame-work of wood behind these flanges held this outer portion of the fixture when the tube was pulled out. The openings A and A′ (three in number at each place) were left for the insertion of a hose with which to throw water on the outside of the tube, and prevent the portion near the steel cylinder from becoming heated. However, very little water was used in this way, and it is probable that the open air space alone prevented any considerable amount of the outside heat from reaching the part of the tube named.

Bolted to the breech end of the tube is another cast-iron cylinder, turned somewhat smaller on the outside than the interior of the steel cylinder, and the latter rested upon this "neck" when the tube was withdrawn. The rod B screwed into the base was used as one of the supports of the apparatus in place; elsewhere, the weight was supported towards the rear near the center of gravity, from a crane, by means of which the whole was put into the furnace. The interior of the neck opens into the bore of the tube through which a copious supply of cold water was run during the operation. The cylinder connected as shown in the sketch, was turned from time to time whilst under heat by hand power applied to the clamp near the muzzle end of the tube. The arrangement of water-pipes enabled this to be done without twisting the hose. When it was desired to turn the tube alone a handspike was placed in one of the sockets shown in the periphery of the nut and rested on the ground.

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*A mercurial thermometer was attached at the top of the furnace to indicate the temperature of the hot-air chamber, but was found unreliable. The highest temperature indicated by it during this operation was 440° Fahrenheit.

The steel cylinder was introduced after the furnace had been raised to a white heat. The following gives a record of the operations at the furnace:

	P. M.
Cylinder placed in furnace	5.22
Blast of furnace turned on	5.24
Cylinder turned partly around	5.25
Cylinder turned all around	5.28
Attempt made to unscrew tube	5.29
Cylinder turned all around	5.30
Attempt made to unscrew tube	5.32
Tube started and unscrewed two turns	5.35
Nut detached by removing bolts	5.37
Tackle attached to muzzle end of tube	5.38
Tube (with nut) pulled out of cylinder	5.40
Whole apparatus removed from furnace	5.42

The whole time occupied was twenty minutes. The cylinder was expanded so that the tube could be turned and the cylinder started by the aid of the screw-thread in thirteen minutes. In five minutes afterwards the cylinder was entirely detached from the tube. After arranging it a constant strain was kept on the tackle attached to the muzzle-end of the tube, and heavy blows were struck with a sledge against the base at the rear side of the furnace. On removal from the furnace portions of the steel cylinder toward the breech end, which remained longest in the furnace, showed a low red heat. It was judged that the maximum temperature of the metal approached 1,000 degrees Fahrenheit, but that this degree of heat was confined to the outer surface of the cylinder was apparent from the fact that the redness disappeared almost immediately. After this the cylinder was left to cool in air, in a position, however, which undoubtedly affected its final shape. It remained in a horizontal position, attached at the muzzle face by the bolts shown in the sketch, while its breech end rested partly upon the "neck" provided to sustain it. In the record of measurements to follow, the bolted end is designated the "top." In the final measurements it was found that the conicalness increased toward the bottom or the end which was inadequately supported; also that the greatest interior diameters corresponded to those measured vertically in the stated position of the cylinder while cooling. I am, therefore, not disposed to attach great weight to the distortion of the bore as finally measured. To have determined this justly the cylinder should have been placed on end on level ground, or on its side, and rolled over from time to time while cooling, preferably the former, for so short a cylinder as this.

The cylinder was dismounted on the third day and finally measured about 66 hours after the heating.

RECORD OF MEASUREMENTS.

TABLE I.—*Interior of the steel cylinder.*

Distance from top.	Original diameters.			Diameters after removal.			Ultimate contraction on diameters.		
	Horizontal.	Vertical.	Mean.	Horizontal.	Vertical.	Mean.	Horizontal.	Vertical.	Mean.
Inches.	*Inches.*	*Inches.*	*Inches.*	*Inches.*	*Inches.*	*Inches.*	*Inch.*	*Inch.*	*Inch.*
0.15	14.001	14.001	14.001	14.002	14.000	14.001	+0.001	+0.001	0.000
3.5	.0005	.0005	.0005	13.998	13.9995	13.9988	−0.0025	−0.001	0.0017
7.0	.000	.000	.000	.9945	.9905	.9925	−0.0055	−0.0085	0.0075
10.5	.0007	.0007	.0007	.995	.9885	.9918	−0.0057	−0.0122	0.0089
12.5	.001	.001	.001	.9985	.991	.9947	−0.0025	−0.01	[illegible]
Mean	14.0006	14.0006	14.0006	13.9976	13.9939	13.9958	−0.003	−0.0067	0.0048

		Inches.
Mean eccentricity,	original	0.
	after removal	0.0037
Conicalness,	original	0.0007
	after removal	[illegible]

The above measurements were made upon diameters marked before the shrinkage. In the following the series of vertical diameters correspond to the position of a *vertical* plane through the axis of the cylinder while cooling.

TABLE II.—*Interior of cylinder after removal.*

Diameters.	Distance from top.					Means.	Ultimate contraction (average).
	0.″15	3.″5	7.″0	10.″5	12.″5		
	Inches.	*Inches.*	*Inches.*	*Inches.*	*Inches.*	*Inches.*	*Inch.*
Vertical	14.0035	14.000	13.9975	13.997	14.000	[illegible]	[illegible]
Horizontal	13.9970	13.9905	13.987	13.9865	13.988	[illegible]	[illegible]
Differences	0.0065	0.0095	0.0105	0.0105	0.012	[illegible]	

From which it is seen that the average contraction of the cylinder in the horizontal direction (referring to position while cooling) was times greater than in the vertical direction. This shows that the ulti- mate eccentricity, at least of the cylinder, was largely influenced by the position while cooling, and an unfortunate doubt rests upon the re- liability of the whole series of final measurements, as indicating the de- formation of the bore due to the applied heat alone. The mean con- tractions (Table I) are least in doubt, yet it is scarcely probable that their inequalities, in the direction of the length, indicate proportional inequalities of heat. However, we note that the mean contraction at the circle of greatest contraction was 0.0089 of an inch, and that the average contraction for the cylinder was 0.0048 of an inch.

TABLE III.—*Lengths of cylinder.*

ORIGINAL.

	Distance from edge.	Diameters.					Average change.
		No. 1.	No. 2.	No. 3.	No. 4.	Mean.	
	Inch.	*Inches.*	*Inches.*	*Inches.*	*Inches.*	*Inches.*	*Inch.*
Outer	0.25	13.703	13.703	13.7045	13.706	13.7041	....
Inner	0.50	.7075	.706	.7075	.708	.7072	....
Means	....	13.7052	13.7045	13.706	13.707	13.7057	....

AFTER REMOVAL.

Outer	0.25	13.702	13.700	13.704	13 704	13.7025	−0.0016
Inner	0.50	.7075	.7075	.708	.709	.7080	+0.0008
Means	....	13.7048	13.7037	13.706	13.7065	13.7053	−0.0004

The changes in length are small and nearly within probable errors of measurement, especially when we consider the handling that the finished faces of the cylinder received in the interval between the measurements; but the results indicate that the effect of the heat, which was greatest near the outside, tended to contract the metal.

MECHANICAL TESTS OF SPECIMEN BARS.

The records of tests which follow give a comparison of tension and compression tests of the metal under the three conditions already referred to. All of the specimens were detached from the cylinder or part cylinder, as indicated in Plate I, after the metal had received the treatment indicated. The original specimen ring was taken from near the middle length of the cylinder as received. Specimen ring C was taken from the middle of the portion used for the experimental section 8-inch breech-loading steel rifle, and the records of tests herewith of specimens taken from those rings are copied from Table I, notes on the Construction of Ordnance, No. 32, while the positions of the specimens are shown in Plate I of that note. Specimen rings A and B were taken from either end of the portion of the cylinder subjected to the high furnace heat from the former, which was contiguous to the position of the original specimen ring; tests by both tension and compression were made for a complete comparison with the original qualities of the metal; from the latter tension tests only were made to determine the qualities of metal in this portion of the cylinder where the outside was observed to be heated to a dull red on removal from the furnace.

Tension tests.—Whitworth steel cylinder (oil tempered) received for experimental pur
length, and 0.25 sq

ORIGINAL QU

[Speci

Marks of specimens.	Extensions per inch of length.						
	0.0013	0.00135	0.0014	0.00145	0.0015	0.00155	0.0016
	Load per square inch of cross-section.						
(Original specimen ring.)	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*
H. tang. outside, 3″.0	47, 000	48, 250	49, 500	51, 500	53, 000	54, 500	55, 500
I. tang. middle, 3″.0	45, 000	46, 500	48, 000	49, 250	50, 000	51, 500	52, 800
J. tang. inside, 3″.0	40, 000	42, 500	44, 000	45, 500	47, 000	48, 250	49, 000
P. radial, 2″.0	42, 000	43, 500	45, 000	46, 000	47, 500	49, 000	50, 500
R. radial, 2″.0	42, 500	44. 000	45, 500	47, 500	49, 000	50, 000	51, 000
Means	44, 125	44, 950	46, 400	47, 950	49, 300	50, 650	51. 7[illegible]

QUALITIES AFTER REMOVAL (BY CUTTING) F

[Speci

(Specimen ring C.)							
J₁. tang. outside, 3″.0	41, 000	42, 750	45, 000	46, 500	48, 000	....	....
J₂. tang. middle, 3″.0	47, 000	48, 500	50, 000	50, 500	51, 000	....	....
J₃. tang. inside, 3″.0	41, 000	41, 750	43, 000	45, 500	47, 000	48, 500	49, 500
Means	43, 000	44, 335	46, 000	47, 500	48, 665	....	....
Mean loss percentage of original qualities.	2. 55	1. 4	0. 86	0. 94	1. 3	....	....
Mean gain percentage of original qualities.	....	....	....	....	....	....	....

QUALITIES AFTER REMOVAL FROM SHRINKAGE

(Specimen ring A.)							
H. EX. tang. outside, 3″.0	42, 000	43, 500	45, 500	47, 500	49, 000	49, 750	51, 000
I. EX. tang. middle, 3″.0	43, 320	44, 580	46, 000	47, 250	48, 000	....	....
J. EX. tang. inside, 3″.0	38, 000	39, 500	41, 250	43, 125	45, 500	47, 250	48, 000
Means	41, 105	42, 525	44, 250	45, 955	47, 500	....	....
Mean loss percentage of original qualities.	6. 8	5. 4	4. 6	4. 2	3. 7	....	....
Mean gain percentage of original qualities.	....	....	....	......	....	....	....
(Specimen ring B.)							
H. EX₁. tang. outside, 3″.0	43, 750	45, 500	47, 000	47, 750	49, 000	50, 500	51, 500
J. EX₁. tang. inside, 3″.0	45, 000	46, 500	48, 000	49, 250	50, 000	51, 250	52, 000
H. EX₂. tang. outside, 3″.0	41, 666	43, 000	46, 000	47, 500	49, 000	50, 500	52, 000
J. EX₂. tang. inside, 3″.0	43, 750	45, 500	47, 000	......	....	....	....
Means	43, 540	45, 125	47, 000	....	....	....	....
Mean loss percentage of original qualities.	1. 32	....	....	....	....	....	....
Mean gain percentage of original qualities.	....	0. 38	1. 29	....	....	....	....

at West Point foundry June 13, 1884, tangential and radial specimens, 3 *and* 2 *inches in inch, cross-section.*

TIES OF METAL.

marked J_1, J_2, J_3.]

0. 0017	0. 00175	Elastic limit.	Extension per inch at elastic limit.	Ultimate strength.	Extension per inch after rupture.	Reduction in area after rupture.	Specific gravity.	Hardness.	Remarks.
Lbs.	*Lbs.*	*Lbs.*	*Inches.*	*Lbs.*	*Per ct.*	*Per ct.*			
58, 000	59, 500	60, 800	0. 0018	104, 000	21. 0	44. 6	7. 8601	....	After 60,800 stretched rapidly and load fell to 57,000.
....	....	52, 800	0. 0016	93, 280	20. 0	36. 4	....	....	After 52,800 stretched rapidly and load fell to 50,000.
52, 000	53, 500	59, 760	0. 0020	97, 000	17. 3	36. 4	....	18. 88	After 59,760 stretched rapidly and load fell to 56,000.
53, 000	....	53, 000	0. 0017	100, 560	12. 0	11. 8	....	20. 93	
....	....	51, 000	0. 0016	91, 600	20. 0	36. 4	....	21. 29	
....	....	55, 472	0. 00174	97, 288	18. 06	33. 1+	7. 8601	20. 37	

EXPERIMENTAL SECTION 8-INCH B. L. STEEL RIFLE.

marked J_4, J_5, J_6.]

....	....	49, 000	0. 00153	88, 160	25. 0	....	....	22. 51	
....	....	51, 000	0. 0015	95, 400	21. 67	....	....	18. 19	
52, 000	53, 500	59, 000	0. 00203	107, 140	15. 0	....	....	19. 39	
....	....	53, 000	0. 00169	96, 900	20. 56	....	....	20. 03	
....	....	4. 5	2. 9	0. 4	....	....	....	6. 2	
....	....	....	....	....	13. 8	....	....	....	

APPLICATION OF A VERY HIGH FURNACE HEAT.

54, 000	....	55, 000	0. 00173	103, 960	19. 67	41. 9	....	....	Failure of specimens after passing elastic limit not so marked as in either of the above cases.
....	....	48, 000	0. 0015	90, 040	24. 00	47. 2	....	....	
51, 000	52, 500	57, 000	0. 00193	104, 200	17. 33	24. 6	....	....	
....	....	53, 330	0. 00172	99, 400	20. 33	37. 9	....	....	
....	....	3. 86	1. 1	....	....	....	....	....	
....	....	....	....	2. 17	12. 56	14. 5	....	....	
54, 000	55, 500	57, 000	0. 001833	100, 120	21. 0	44. 6	....	....	
56, 000	57, 500	60, 000	0. 001933	104, 160	17. 67	24. 6	....	....	
53, 666	....	53, 000	0. 001633	93, 040	22. 33	39. 2	....	....	Failed rapidly under load of 55,000 pounds per square inch.
....	....	47, 000	0. 001400	93, 160	17. 67	39. 2	....	....	
....	....	54, 250	0. 001699	97, 620	19. 67	36. 9	....	....	
....	....	2. 20	2. 35	....	....	....	....	....	
....	....	....	....	0. 34	8. 91	11. 45	....	....	

Compression tests.—Whitworth steel cylinder (oil-tempered) received for experimental pur inches in length, and 0.50

ORIGINAL QUALI

Marks on specimens.	Compression two per inch					
	0.0013	0.00135	0.0014	0.00145	0.0015	0.00155
	Load per square inch of cross-					
(Original specimen ring.)	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*
L., tangential outside, 5.0 inch	44,000	45,325	46,000	47,000	49,000	....
K., tangential inside, 5.0 inch	44,000	46,000	47,000	48,000	50,000	52,000
M., radial, 4.0 inch	42,000	43,500	45,500	47,500	48,325	48,8[illegible]
N., radial, 4.0 inch	40,500	42,500	45,000	46,250	47,000	47,500
Means	42,625	44,330	45,875	47,190	48,580	....

QUALITIES AFTER REMOVAL (BY CUTTING) FROM

(Specimen ring C.)						
C J_1, tangential outside, 5.0 inch	46,000	48,000	49,500	51,000	52,000	53,500
C J_2, tangential outside, 5.0 inch	42,000	43,000	44,000	45,000	46,000	47,750
C J_3, tangential outside, 5.0 inch	37,860	39,285	41,000	42,500	44,000	46,000
Means	41,955	43,430	44,865	46,165	47,335	49,0[illegible]
Mean loss percentage of original qualities	1.6	2.0	2.2	2.17	2.55	....
Mean gain percentage of original qualities	....	....	....	....	....	....

QUALITIES AFTER REMOVAL FROM SHRINKAGE BY

(Specimen ring A.)						
L. ex., tangential outside, 5.0 inch	43,333	45,000	46,666	48,333	50,500	52,000
K. ex., tangential inside, 5.0 inch	45,000	46,375	47,750	49,125	50,500	52,000
N. ex., radial, 3.94 inch	42,500	43,750	45,000	46,250	47,500	48,750
P. ex., radial, 3.94 inch	43,333	45,000	46,833	48,666	50,500	52,500
Means	43,541	45,031	46,562	48,093	49,750	51,3[illegible]
Mean loss percentage of original qualities	....	....	....	....	....	....
Mean gain percentage of original qualities	2.14	1.58	1.47	1.91	0.35	....

poses at West Point Foundry, June 13, 1884. Tangential and radial specimens 5 *and* 4 *square inch cross-section.*

TIES OF METAL.

of length.				Elastic limit.	Per inch at elastic limit.	Ultimate strength.	Remarks.
0. 0016	0. 00165	0. 0017	0. 00175				
section.							
Lbs.	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*	*Inches.*	*Lbs.*	
....	....	....	....	49, 000	0. 0015	....	Rapid deflection at 50,000.
52, 650	53, 500	55, 000	56, 000	59, 000	0. 001775	....	Rapid deflection at 60,000.
50, 500	52, 500	54, 000	56, 250	57, 000	0. 0018	....	
49, 000	51, 500	53, 000	....	54, 000	0. 001733	....	Gave suddenly at 54,000.
....	....	....	....	54, 750	0. 001702	....	

EXPERIMENTAL SECTION 8-INCH B. L. STEEL RIFLE.

55, 000	56, 000	57, 000	....	57, 000	0. 0017	88, 760	Triple flexure; bent 180° without fracture.
50, 000	51, 000	52, 000	53, 500	55, 000	0. 001825	87, 840	
47, 500	49, 000	50, 000	51, 500	58, 000	0. 00195	87, 920	Triple flexure.
50, 835	52, 000	53, 000	....	56, 665	0. 001825	88, 175	
....	....	....	....	....	....	....	
....	....	....	....	3. 5	7. 2	....	

APPLICATION OF A VERY HIGH FURNACE HEAT.

53, 000	54, 000	55, 000	55, 500	57, 000	0. 00185	89, 200	Triple flexure.
54, 000	55, 000	56, 500	58, 000	61, 000	0. 00185	102, 100	Do.
50, 000	51, 000	52, 000	53, 000	53, 000	0. 00175	101, 600	Do.
....	....	....	....	54, 000	0. 00160	101, 600	Do.
....	....	....	....	56, 250	0. 001762	98, 625	
....	....	....	....	....	....	....	
....	....	....	....	2. 73	3. 52	....	

In the tension and compression tests from original specimen ring (specimen ring A) we have a fair exhibit of the effect of the high furnace heat upon the qualities of the metal. Under the tension tests there is an appreciable loss of elastic strength, but there is a gain in ultimate strength and ultimate extension and a greater reduction in area after repture. Under the compression tests there is a gain throughout, and the specimens stood better after passing the elastic limit. It must be remembered, moreover, that there should have been expected a certain loss of elastic strength in the metal under tension tests, due to the fact that the cylinder was in an intermediate stage subjected to shrinkage upon the wrought-iron tube. The tension tests from specimen ring B show a very slight variation from the original qualities, but rather a gain than a loss. This ring being remote from the original one does not justify a direct comparison of the results, yet these specimens were taken from the extremity of the cylinder, which was exposed to the greatest heat of the furnace, and where the surface of the metal was heated to a dull red.

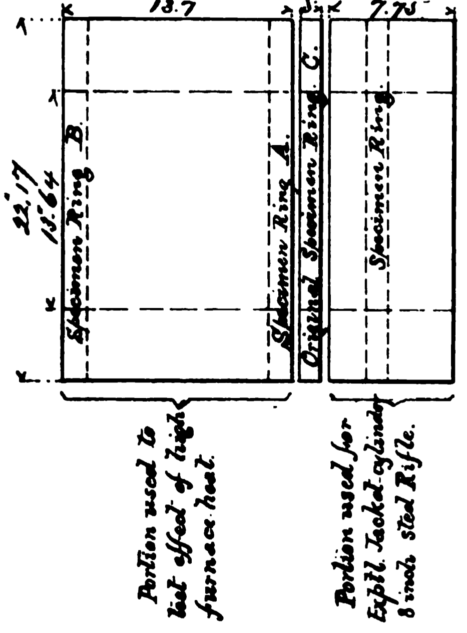
In regard to the principal object of the experiment, therefore, it may be stated that the quality of tempered Whitworth gun steel is not seriously injured by subjecting the metal to a very high furnace heat for a brief period; or, to be more explicit, the quality of the metal in this case was not injured by the white heat of a furnace applied a sufficient length of time to raise the outer surface of the metal to a dull red heat.

On the other hand, this experiment shows that it cannot be expected to preserve the original dimensions of the bore of the cylinder under such circumstances. The deformation of the bore may probably be regulated to a certain extent by the position of the cylinder whilst cooling, yet a considerable, if not an unequal, amount of contraction may be anticipated throughout the bore. In cases, therefore, which arise in practice, where it is desired to reassemble the cylinder in the same place from which it is removed from shrinkage by the application of a high furnace heat (or other heat, such as molten cast iron) it is recommended that the cylinder should be reassembled at the same heat, or, if this is not expedient, that it should not be allowed to cool until such assemblage is made. By this means the deformation of the cylinder will be prevented, and in the final shrinkage the heated fibers will adjust themselves (having lost little, if any, of their original strength) under the resistance offered by the interior body upon which the cylinder is shrunk. In all cases it is understood that the heating of the metal should be made as nearly uniform as possible throughout the cylinder.

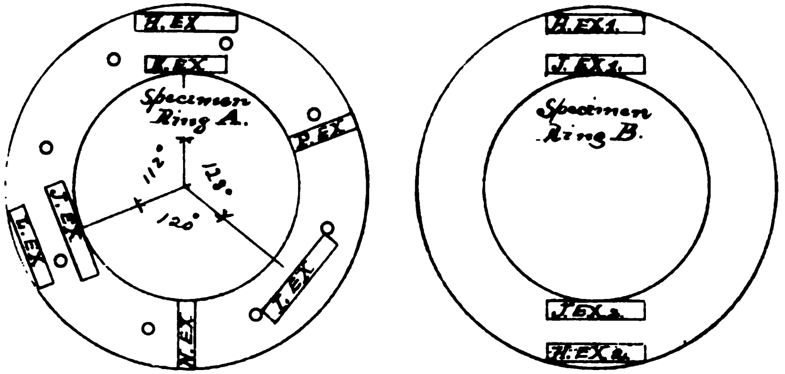
Very respectfully,

R. BIRNIE, JR.,
Lieutenant of Ordnance.

CYLINDER-WHITWORTH STEEL
(Factory No 1865)


13.7
1.25
7.75
22.17
13.64
Specimen Ring B.
Specimen Ring A.
Original Specimen Ring C.
Specimen Ring.
Portion used to test effect of high furnace heat.
Portion used for Exptl. Jacket-cylinder 8 inch steel Rifle.

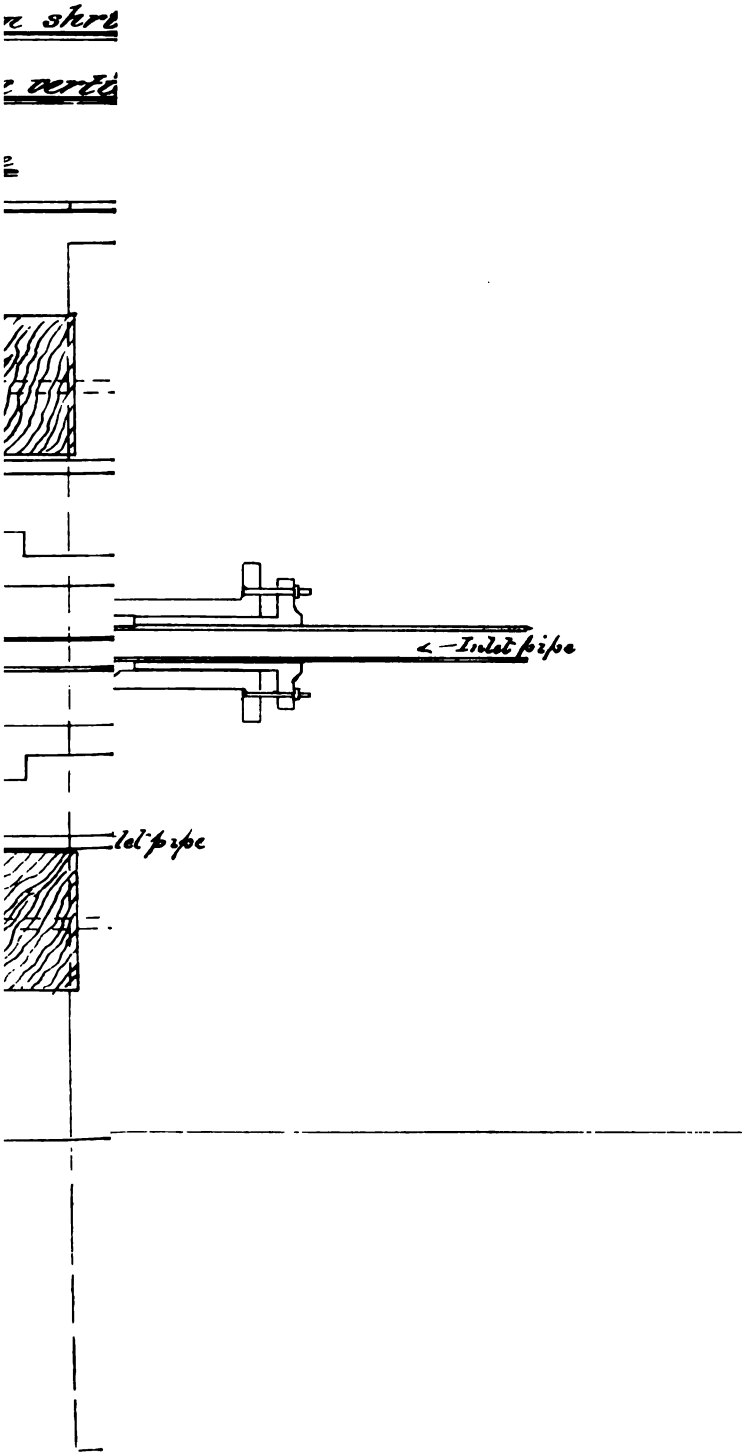
POSITION OF TEST-SPECIMENS.



Note. For position of specimens from Original specimen ring, and specimen ring from middle of Experimental Jacket-cylinder, see Figs 1 & 3. Plate I., Notes on the Construction of Ordnance No. 32.

H Ex1 pt2 v3 49 I

PLATE II.



APPENDIX 32.

ANNUAL REPORT OF CAPT. D. A. LYLE, INSPECTOR OF ORDNANCE AT THE SOUTH BOSTON IRON WORKS, BOSTON, MASS., FOR THE YEAR ENDED JUNE 30, 1885.

(1 plate.)

The CHIEF OF ORDNANCE, U. S. ARMY,
Washington, D. C.:

SIR: I have the honor to submit the following report upon the operations undertaken for the Ordnance Department, U. S. A., by the South Boston Iron Works during the fiscal year ending June 30, 1885.

During this period the fabrications given in the subjoined list have been undertaken or have been in progress.

List of fabrications.

Orders or contracts for fabrication.	Date of order or contract.	Fabrication.
Unfinished at beginning of fiscal year.	July 14, 1883	1. Conversion of one 6.5-inch Mann B. L. R. from a 10-inch Rodman S. B. gun.
	Sept. 10, 1883	2. Conversion of one 8-inch Yates B. L. R. from a 10-inch Rodman S. B. gun.
		Cast-iron bodies for:
	Sept. 24, 1883	3. One 12-inch M. L. mortar hooped with steel.
		4. One 10-inch wire-wrapped B. L. R.
		5. One 12-inch cast-iron B. L. R.
		6. One 12-inch B. L. R. hooped and tubed with steel.
		7. One 12-inch B. L. R. with wire-wound steel tube.
	Dec. 12, 1883	8. 500 solid shot for 15-inch Rodman S. B. guns.
	Apr. 2, 1884	9. Experimental cylinder for 12-inch M. L. R. mortar.
Received during the fiscal year ending June 30, 1885.	June 30, 1884	10. Finishing and assembling 12-inch M. L. R. mortar.
	June 30, 1884	11. Finishing and assembling 12-inch B. L. R. hooped and tubed with steel.
	June 30, 1884	12. Finishing and assembling 12-inch tubed rifles.
	June 30, 1884 Apr. 22, 1885	13. Experimental cylinder for 12-inch B. L. R. hooped and tubed with steel.
	Aug. 15, 1884	14. Test specimens from experimental cylinder for 12-inch mortar after unhooping.
	Aug. 26, 1884	15. Test specimens from 12 inch cast-iron B. L. R.
	Nov. 28, 1884	16. Wooden model for 12-inch cast-iron B. L. R. for obtaining center of gravity.
	Dec. 1, 1884	17. 1,000 8-inch Butler chilled shot.
	Jan. 9, 1885	18. Wooden models for 8 and 10 inch B. L. R., steel.
	Jan. 20, 1885	19. 50 8-inch Butler sabots for B. L. projectiles.
	Apr. 3, 1885	20. 10 8-inch Butler chilled shot.
	Mar. 17, 1885	21. 4 8-inch Winslow's nitro-glycerine shell (for Ordnance Board).

Of the above list the following numbers have been completed and special reports already made to the Ordnance Office, viz: Nos. 1, 2, 3, 4, 5, 8, 9, 10, 13, 14, 15, 16, 17, 18, 19, 20, and 21.

The unfinished work at the close of the fiscal year comprises Nos. 6, 7, 11, and 12, relating to the 12-inch hooped and tubed, and to the 12-inch tubed B. L. rifles.

In addition to the reports noted above, Lieut. H. D. Borup, Ordnance Department, U. S. A., assistant inspector of ordnance, has made and submitted exhaustive reports upon "The Use of Petroleum as Fuel," and the "Hotchkiss Revolving Cannon."

I.—12-INCH HOOPED AND TUBED B. L. R.

1. *The cast-iron body.*

The body is ready for the reception of the steel tube. The interior cavity for the tube is counterbored to the finished size and the screw-thread at the breech has been cut. The bore in front of the tube has been reamed up to a diameter of 11.95 inches, or 0.05 inch less than the finished bore. The remaining .05 inch will be finished simultaneously with the bore of the tube.

Since the body has to be placed muzzle downward in a pit for the insertion of the steel tube, a cylindrical mass has been left on the muzzle for the gun to rest upon in the pit and to secure a larger bearing-surface at the muzzle. To prevent injury to the exterior surface from indentations or any accident in handling during the tubing operations an excess of metal has been left upon the body, as follows:

1.—Chase-diameter 0.9 greater than finish size.
2.—Shoulder in front of hooping about 1 inch too long.
3.—Hooping surface, diameter 0.6 inches greater than finish size.

2. *Whitworth steel tube.*

This tube was received from Sir Joseph Whitworth & Co. February 9, 1885. It has been bored to a diameter of 11.9 inches and rough turned to within 0.5 inch of the finished diameter. The company are awaiting the results from the experimental cylinder and the determination of the shrinkages, in order to proceed with the finished turning of the exterior of the tube.

3. *Midvale steel hoops.*

All the hoops, except two not yet received from Midvale, are bored and faced, and are ready for application.

4. *Breech mechanism.*

The several parts composing the breech fermature are completed, except the final fitting and some alterations ordered after the parts were nearly finished.

II.—12-INCH B. L. RIFLE WITH WIRE-WRAPPED STEEL TUBE.

1. *The wire-wound steel tube.*

The tube was made by Sir Joseph Whitworth & Co., and has been sent to Watertown Arsenal to be wound with wire and prepared for insertion.

2. *The steel breech bushing.*

This is to be screwed in to hold the steel tube in place and to provide a seat for the French interrupted screw fermature. It has been rough-turned.

3. *Breech mechanism.*

The several parts of this mechanism are nearly completed and are ready for final fitting.

4. *The cast-iron body.*

Two castings, breech down, have been made for the body, both of which have been rejected. The company are preparing to make a *third* casting, breech up, the Chief of Ordnance having granted permission to employ that method for this casting.

5. *First casting, 12-inch tubed B. L. rifle.*

The first attempt to cast the 12-inch tubed rifle was made July 9, 1884.

(*a*) *Furnace charges.*

[Richmond iron used.]

Grade of iron.	Furnaces.			
	No. 1.	No. 2.	No. 3.	Total.
	Pounds.	*Pounds.*	*Pounds.*	*Pounds.*
No. 2	13,668	13,668	13,668	41,004
No. 3, soft	17,668	17,668	17,668	53,004
No. 3, hard*	21,998	21,998	21,998	65,994
Remelted	26,666	26,666	26,666	79,998
Total	80,000	80,000	80,000	240,000†

*Classed at this foundry as No. 4 Richmond.
†Equal to 107.1 tons of 2,240 tons of each.

(*b*) *Coal used.*

The quantity of coal used in melting was not given by the company, but it is presumed that it amounted to about 45 or 50 tons. The former quantity was reported by the company as used in melting the iron for the second casting, which contained 6,000 pounds more metal.

(*c*) *Details of melting and casting.*

Furnace.	Fire lighted at, July 8, 1884.	Iron m July	Time in fusion July 9, 1884.	Furnace tapped at, July 9, 1884.	Melted iron out of furnace, July 9, 1884.
	p. m.	*a. m.*	*h. m.*	*p. m.*	*p. m.*
No. 1	9.30	9	3 12	12.12	12.22
No. 2	8.15	9	3 16	12.16	12.25
No. 3	9.30	9	3 20	12.20	12.40

Water turned on in core-barrel at 12.11 p. m. July 9, 1884.
Mold filled at 12.40 p. m-July 9, 1884.
Time occupied in casting, 28 minutes.

	o
Temperature of water entering core-barrel at 12.40 p. m	70
Temperature of water leaving core-barrel at 12.40 p. m	106
Difference	36

Flask burst between 1 p. m. and 1.30 p. m. July 9, 1884.
Casting lost July 9, 1884.

In addition to the reports noted above, Lieut. H. D. Borup, Ordnance Department, U. S. A., assistant inspector of ordnance, has made and submitted exhaustive reports upon "The Use of Petroleum as Fuel," and the "Hotchkiss Revolving Cannon."

I.—12-INCH HOOPED AND TUBED B. L. R.

1. *The cast-iron body.*

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Difference	36

Flask burst between 1 p. m. and 1.30 p. m. July 9, 1884.
Casting lost July 9, 1884.

6. *Loss of first casting.*

The metal was all poured by 12.40 p. m. About 1.30 p. m. the third section of the flask, estimating from the bottom, broke, and allowed the molten metal to escape and flow around the lower part of the flask and fill the bottom of the pit. In its downward rush the swash of the metal struck the mouth of one of the air-flues in the side walls of the pit, and threw a jet of molten metal to the roof of the foundry, setting it on fire.

The fire destroyed the roof and charred the rafters, joists, and the wood work of the large cranes. The damage by fire was inconsiderable, and was covered by insurance. I understood at the time that the insurance company or companies repaired the damaged buildings themselves without expense to the South Boston Iron works. On July 26 the mass had cooled down sufficiently for examination, and it was found that the third section from the bottom had been ruptured. On July 30 (see my letter to Chief of Ordnance bearing that date) Mr. Wood, the foreman in the ordnance foundry, reported to me that he believed the rupture was due to the breaking of the clamps on the third section, and that part of one-half of third section of flask has broken diagonally, due to the pressure of the iron. Upon inspection his opinion appeared to me to be reasonable. The broken part of the half section appeared to have given away at the bottom of the section (third), and been bent outwards, rupturing the half section diagonally and permitting the iron to escape. This portion of the flask-section was found with its convex side turned upward, thus indicating that it had given way first at the bottom. The clamps were probably old—some made of cast iron and some of wrought iron.

A clamp might have been cracked slightly before it was put on, and might not have been noticed even by the most careful workman. As the flask held for one and a half hours, it is not improbable that the expansion due to the heat may have had something to do with the breaking or slipping off of the clamps, if that was the cause of the accident.

At first I attributed the accident to weakness of the flask and the heavy head of molten metal, but on further reflection I am inclined to the opinion that one or more of the clamps must have given way. I am informed that the breaking of clamps had occurred in former years.

No person can state positively the exact cause of the disaster.

The company informed me that they were going to make the new sections, to replace those lost, with walls 3 inches thick instead of 2½ inches.

Nearly all of the core-barrel was saved.

The jet of melted metal that ignited the roof knocked off the hose that supplied the core-barrel with water, so that not more than 4,000 gallons of water had been expended.

The molten metal, after escaping from the ruptured section into the pit, surrounded the lower sections of the flask, and melted the whole together so as to form a solid mass in cooling.

> The casting formed a huge cheese-like disk in the bottom of the pit, and was very difficult to remove. It was about 10 feet in diameter, 7 or 8 feet thick, and weighed about 140 tons.[*]

The time between July 26 and September 1 was employed by the company in making preparations to raise the mass from the pit. The first attempt was made September 4, 1884, but the mass was not clear of the pit until some time during the week ending October 4, 1884.

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[*] "Casting of heavy guns at South Boston," by Capt. D. A. Lyle. (See "Abstract of Proceedings of Society of Arts of Massachusetts Institute Technology," 1884–1885, p. 93.

7. *Larraway's method of hoisting mass from pit.*

(Plate I.)

The removal of this mass from the pit was a difficult undertaking. Mr. Larraway, a very able mechanical engineer, who is superintending the construction of some barrel machinery at the foundry, conceived the idea of applying the pumps, or rams, of his hydraulic presses to raise it from the pit. To do this he constructed two side frames, each consisting of a ground sill and four uprights, with a tie-beam at the top, all of heavy timber. These were set up one on each side of the pit. Upon these side frames four simple wooden trusses were placed, each carrying three 2½-inch wrought-iron suspension rods. Each truss was trapezoidal in shape, and had two struts, inclined in opposite directions, to support the middle point of the upper or compression member. The twelve suspension rods were composed of enough sections to reach from the bottom of the pit to the tops of the trusses. The upper sections of each rod had a screw-thread cut on their surfaces for about twelve feet of their length. Holes were drilled in the mass of metal and screw-bolts inserted, to which the rods were made fast.

Three rods on each side passed up through the side trusses, and the nuts on the ends enabled the workmen to follow up and hold any lift made by the two middle trusses and their rods, which did the hoisting. The middle trusses had three suspension rods each, made fast to the mass of iron in the pit, and were raised bodily by the pistons of the two hydraulic presses placed immediately under the opposite ends of the trusses. The pressure was transmitted from the pistons to the trusses by massive blocks of timber.

A small Baxter engine furnished the power to drive the steam-pump that forced the water into the hydraulic presses. When the middle trusses had been raised a vertical distance equal to the stroke of the piston, the strain was thrown on the side trusses and their rods, the middle trusses lowered, the nuts on their rods being screwed down at the same time to maintain a bearing. A new hold was then taken and the action repeated until the mass was lifted to a distance equal to the length of one section of the suspension rods. One section at a time was removed consecutively from each rod, and when all was ready the lifting was repeated in the same manner as before, until the mass of iron was hoisted clear of the pit. It was then transported on rollers to the yard, where it still remains.*

Plate I, appended to this report, gives a side and end elevation of the apparatus used by Mr. Larraway in raising the metal from the first casting from the bottom of the pit, and the method of its application.

This unwieldy mass contained the metal from three sections of the flask and the sand of the mold, besides the metal pertaining to the gun.

8. *Second casting (12-inch tubed rifle).*

The second casting for the 12-inch tubed B. L. Rifle was made December 23, 1884. The details relating to furnace charges, melting, casting, and the cooling table are appended, marked Table I.

This casting (weight 109.5 tons) was cooled in 140 hours, during which time 31,121 cubic feet of water passed through the core barrel and gun. For the 12-inch cast-iron B. L. rifle (weight 108 tons) 157¼ hours were required for cooling and an expenditure of 44,234 cubic feet of water.

The metallurgic conditions appeared to be more favorable than with either of the other guns, and the iron was poured at an apparently satisfactory temperature.

The fracture of the "test sticks" from two of the furnaces appeared a little harder and more crystalline than was desired, but this appearance was attributed to the rapid chilling in the wet sand, and it was believed that the large casting would show about the qualities desired. The method of using test sticks is only valuable as an approximate index of the working of the furnaces in the hands of an experienced foreman, who can judge of the condition of melted iron by comparison, from the knowledge obtained in previous trials with the same iron.

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* Casting of heavy gun at South Boston, by Capt. D. A. Lyle. See "Abstract of Proceedings of Society of Arts of Massachusetts, Institute Technology," 1884–1855, pp. 93, 94.

It is a very rough method at best, but it is the only one available in such work, on account of the rapidity and ease with which such tests may be made.

The casting was hoisted from the pit by February 14, 1885, and was placed in the lathe during the week ending March 7, 1885.

As far as external appearances went, the casting seemed to be a good one.

9. *Cooling the casting.*

The Rodman system of cooling from the interior consists in having an axial core barrel, through which cold water is circulated to carry off the heat from the inside and cause the melted metal near the bore to harden in concentric cylindrical layers, beginning on the inside and extending gradually toward the exterior, thus bringing a strain of compression upon the layers nearest the surface of the bore. To facilitate this operation and secure reasonable uniformity in the cooling, it is necessary that the exterior of the mass of metal be retained in a molten state as long as possible, in order to allow time for the interior layers to cool consecutively and "set."

In order to preserve this molten state for the exterior as long as possible, a fire is built in the bottom of the pit around the flask, to keep the flask and the air in the pit around the casting hot. Just enough draft is permitted to keep the fire burning. The top of the pit is covered to regulate the draft and keep in the heat.

The contract (of September 24, 1883) provides that—

> All these castings shall be made hollow and be cooled from the interior (except as hereinafter provided for *) by a current of air or water, the exterior at the same time being kept hot either by a fire built around the flask within the casting pit, or by filling the space between the flask and the pit walls with some suitable non-conducting material as may be desired by the United States. Specimens of the metal taken from the lower end of the sinking heads shall in each case have an ultimate tenacity of not less than 30,000 pounds, nor more than 37,000 pounds per square inch. The exterior dimensions of the rough castings shall be such as to allow the finishing of the guns to accurately conform to the dimensions given on the drawings hereto attached, and also to assure a uniform surface when finished; and the castings shall be sound, free from cavities, soft spots, and flaws.
>
> * * * * * * *
>
> The casting for the body for the twelve-inch breech-loading rifled gun, finished in readiness for the insertion of a wire-wrapped steel tube and breech bushing shall be made breech down, the total weight of the sinking head shall be at least one-sixth of the total weight of the rough gun casting, and the body shall be finished accurately and completely on the exterior. The recess for the tube shall be finished, bored in accordance with the drawing.

The Chief of Ordnance directed that the casting be made breech down.

10. *Variations in cooling from the Rodman method.*

After the accident with the first casting, Mr. Hunt, president of the South Boston Iron Works, attributing its loss to the weakness of the

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* This exception has reference to an alternate method for the 12-inch hooped and tubed gun.

and to the fact that the gun was cast breech down, proposed to
nd the flask with sand, well rammed, as high as the trunnions in
to support the flask. He spoke to me in regard to this project,
stated that I could not authorize such a departure from the recog-
methods of casting; that I feared the rapid absorption of heat by
mp sand would cool the exterior too rapidly. At his suggestion,
er, I wrote to the Ordnance Office, explaining his proposed modi-
n.

reply I received deprecated a departure from the usual methods,
was remarked that in case sand was used it would be prudent to
t thoroughly dried. I inferred from this reply that the Depart-
lid not intend to give any additional instructions, and intended
le by the provisions of the contract and leave the subject of the
ulation to the responsible founder, who, when president of the
Boston Iron Company, in his letter to the Committee on Naval
s,* dated February 27, 1882, says, in speaking of the subject of
nstruction:

> pecialty, we have devoted years of practical labor and thought to this ques-
> d believe that the accumulated experience of forty years justifies our speak-
> h proper confidence upon the subject now claiming your attention.

who, again, in his letter to General S. V. Benét, Chief of Ord-
U. S. A., dated Boston, January, 1882, states:

> outh Boston Iron Company has been actively engaged in the manufacture of
> e for the United States Government for more than half a century. During
> g period of service its record has been of the highest character, and at all
> has faithfully executed its engagements with the Government. It has added
> from time to time to its machinery and fixtures, until it is in condition to
> e cannon of the largest caliber without delay, and until the value of its plant
> than a million dollars.
>
> * * * * * * *
>
> ing to continue the leading position we hold in the line of our business, and
> g that we have the experience and ability at command to successfully pro-
> nnon of large caliber of iron or steel from *American* ores,† &c.

parted to Mr Hunt the misgivings of the Department and my-
regard to the use of damp sand, or a departure from Rodman's
d. He then decided to place a dry brick wall 8 inches thick next
flask, and ram sand exterior to this, so as to support the flask.
onversation with Mr. Hunt about this wall I expressed the opin-
t I thought the wall better than to put damp sand directly against
sk, but that I was not satisfied that the brick and sand were suf-
ly non-conducting to be safe. Mr. Hunt differed with me and
that he thought the wall would be a good non-conductor and
keep in the heat. The subject was then dropped.

company placed the flask in the pit, built the 8-inch brick wall
l it as high as the top of the trunnion section, and placed a fire
pit around the flask at that point.

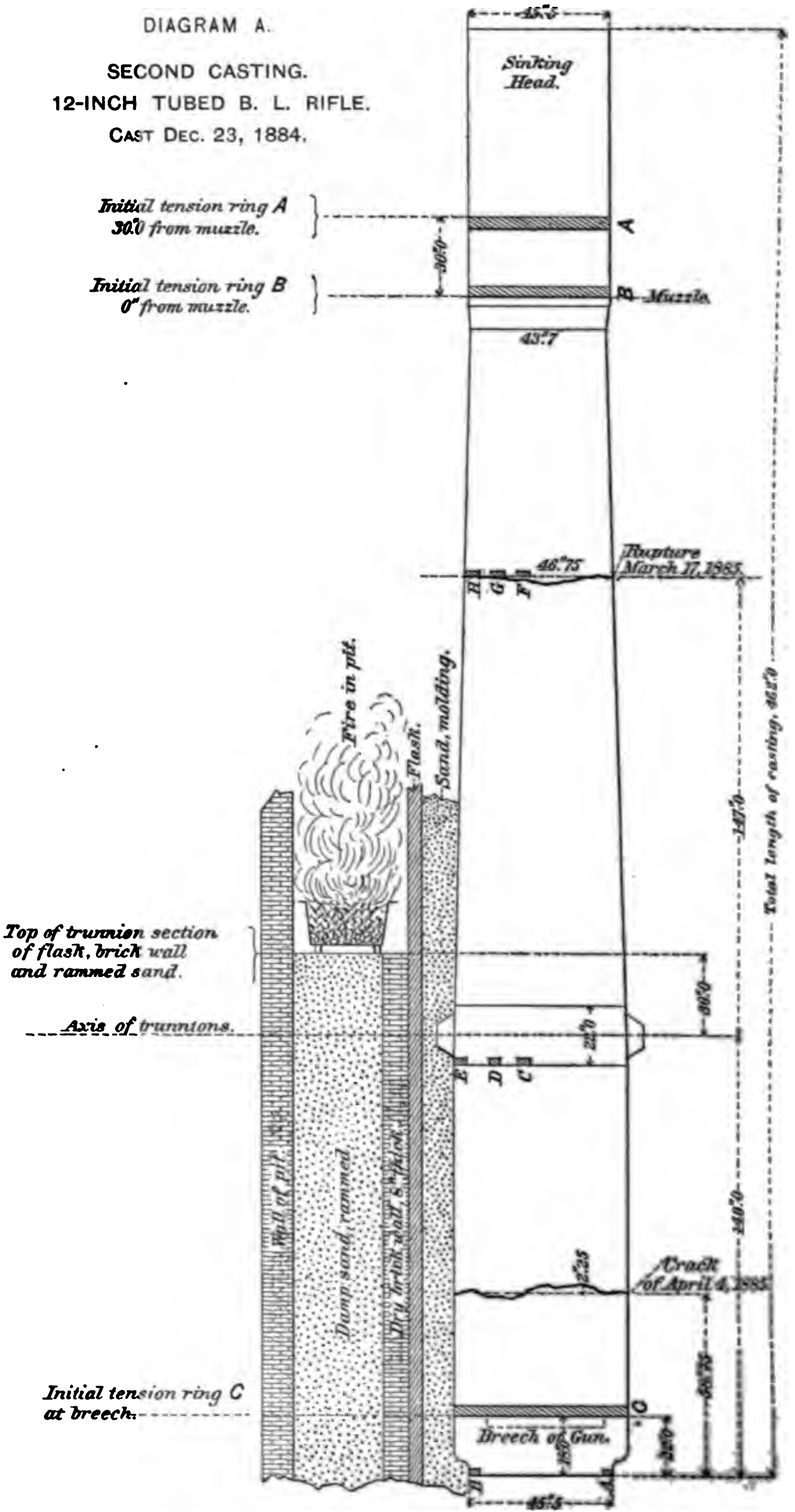
arrangement is fully illustrated in Diagram A, which follows:

"The Construction of Ordnance," by William P. Hunt, president of the South
Iron Company, Boston, 1882, p. 70.

"The Establishment of Steel Gun Factories in the United States," by Lieut.
aques, U. S. N., p. 541. The italics are mine.—D. A. L.

DIAGRAM A.

SECOND CASTING.
12-INCH TUBED B. L. RIFLE.
CAST DEC. 23, 1884.


45.5
Sinking Head.
Initial tension ring A 30.0 from muzzle.
A
30.0
Initial tension ring B 0" from muzzle.
B Muzzle.
43.7
46.75
H
G
F
Rupture March 17, 1885.
147.0
Total length of casting, 462.0
Fire in pit.
Flash.
Sand, molding.
Top of trunnion section of flask, brick wall and rammed sand.
30.0
Axis of trunnions.
22.0
E
D
C
Wall of pit.
Damp sand, rammed
Dry brick wall, 8" thick.
22.5
Crack of April 4, 1885.
140.0
58.75
Initial tension ring C at breech.
C
Breech of Gun.
18.0
32.0
B
A
45.5

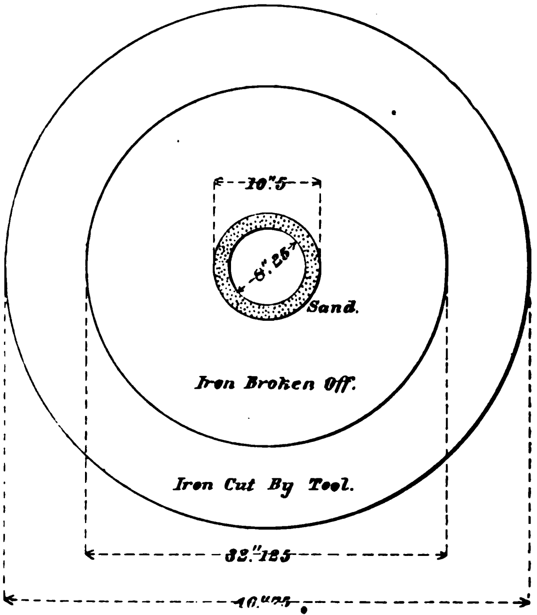
11. *Transverse rupture of second casting.*

After adjusting the casting in the lathe, the sinking head and first initial tension ring (A) were cut off, and then gang-tools were employed to remove portions of the exterior by turning annular grooves in the body. The metal between these grooves was to be wedged off. On Saturday, March 14, the workman noticed a slight crack in the casting in the bottom of the annular groove, cut at 147 inches from the axis of the trunnions (or 287 inches from the breech of casting), but it was not reported to the inspectors. On the evening of March 17 the casting broke short off in the lathe. The ruptured section, shown in Diagram B, had an exterior diameter of 32.125 inches, and an interior diameter of 10.5 inches. The exterior diameter of the casting at this point was 46.75 inches; the depth of the groove cut by the tool was 7.3+ inches. The surface of fracture was curved with the convexity turned toward the breech of the casting. The metal in the fractured surface had a brittle arenaceous appearance, white and gray mottled.

On April 4, 1885, a cut ⅞ inch wide and 6⅝ inches deep was made in the body at 58.75 inches from breech, when a crack was discovered. The exterior diameter at the bottom of this slot was 43.75 inches.

On April 7 another cut, 5⅞ inches deep, was made at 31.5 inches from the breech, and wedges driven in. The 31.5-inch breech section split off with ease. The fracture was convex towards the breech, but the versine of the longitudinal section was only 0.5 inch, instead of about two inches, as found for first rupture. The thickness of metal ruptured was over 34 inches, or a little over 17 inches on each side of the bore. Fractured surface, mixed white and mottled; iron, hard, sandy-looking, very brittle, and crumbling; grain, finer around core barrel than elsewhere. The section of April 4, 58.75 inches from breech, was next

DIAGRAM B.



Scale: 1″ to 8″.

12-inch tubed cast-iron B. L. R., showing area of broken section, ruptured March 17, 1885, 147 inches in front of axis of trunnions, or 287 inches from the breech of the casting.

wedged off. It broke with a somewhat irregular fracture, a convexo-concave surface indicated in Diagram A. A basin-shaped cavity, 2¼ inches deep, was left in the muzzle end at this section, showing irregular strains at this point. Fracture, mottled, with hard white points bright and lustrous; metal apparently brittle. Near the core, and extending radially about 3 inches from the bore, the surface of the fracture was slightly discolored by rust, indicating that a crack had existed there while water was still in the bore.

After the first rupture the company began cutting the gun into suitable sections for remelting, all of which were wedged off with ease. Up to and including April 18, 1885, the casting had cracked transversely at eight different points (including the first point of rupture) while the annular grooves were being cut and before the resort to wedging off.

It will be seen from the foregoing that the Department provided for two methods of keeping the pit hot; either—

(1) By means of a fire placed around the flask at the bottom of the pit, or (2) by filling the space around the flask with some non-conducting material.

The company did not adopt either of the methods prescribed by the contract, but adopted and used part of each; that is, they built a fire in the pit around the upper part of the flask above the trunnions and filled the lower part of the space between the pit and flask with what they claimed, and probably believed, to be a "suitable non-conducting" medium.

In order to secure, as far as possible, *uniformity* in cooling upon the exterior of a casting, any person having the slightest acquaintance with the principles and laws of physics, or the art of molding, knows that the more homogeneous the enveloping material throughout the zone penetrated by the heat, whether it be gaseous or solid, the more uniform will be the *rate* of cooling. The absolute cooling effect will depend upon the densities and conducting powers of the circumjacent media, supposing the particles to remain relatively at rest and not disturbed by currents of air, &c. Thus, if air be used as the surrounding medium, the rate of cooling and the cooling effect will be very different if the air remain at rest from what it would be were the air kept in circulation, the heated air being removed and replaced by cold air.

In view of these facts, it would have been better, as far as *uniformity* of cooling was concerned, to have either surrounded the flask with the brick wall and sand all the way up, or to have built a fire at the bottom of the pit and kept the flask surrounded by hot air at as nearly a uniform temperature and with as little a current as possible.

The remarks regarding uniformity of cooling are based upon the supposition, of course, that the casting is a perfect cylinder, without any protuberant masses. In this casting, however, the breech end had the thickest metal and the chase the least thickness, but to counterbalance this the thin metal was protected by the greater thickness of dry sand inside the flask, and would not radiate its heat to the medium surrounding the flask so rapidly as would the thick metal at the breech with its lighter protection of dry sand inside the flask. This casting also had masses projecting to form the trunnions, which would interfere with the uniformity of cooling about that section.

The company, however, adopted a mixture of the two methods of exterior cooling. They kept the air around the top of the flask hot for a time; and from the bottom of the pit to the top of the trunnion section was filled with the brick wall and moist hard-rammed sand.

Any intelligent master molder could have foreseen that the conditions were exactly similar to those employed in casting chilled projectiles or chilled rolls; where the part to be chilled is surrounded by a metallic envelope on account of its good conducting properties and the unchilled parts are molded in sand or loam, which is a comparatively poor conductor of heat.

12. *Difficulty in molding.*

In relation to the molder's task in preparing for heavy castings, Appleton's Cyclopædia of Mechanics, Vol. II, p. 452, has the following:

> The casting is a very intricate process, requiring good engineering abilities, skill in drafting, and experience in the designs as well as in those who execute the work. * * * He (the molder) has also to provide channels and gateways for the pouring of the metal, and they must be so arranged as to secure its perfect flowing to every part, and as nearly as possible its simultaneous cooling. Allowance must also be made for shrinkage, and an almost infinite number of precautions suited to particular exigencies as they arise must be observed. The drafting requires great forethought and calculation, and the execution not only involves a perfect comprehension of the plan, but a constant vigilance in avoiding errors and causes of miscarriage.

The above paragraph indicates clearly the necessity for great precautions in molding. In this case the mold had a cylindrical sinking head (see diagram A), then tapered for a foot to the neck, and had a reverse conical surface, large end down, with projecting masses for the trunnions, below which point it was practically cylindrical. A comparison of the dimensions of the mold and the corresponding dimensions of the casting at the same points is given below.

Point taken.	Pattern.	Castings.*	Difference.
	Diameters.	Diameters.	
	Inches.	*Inches.*	*Inches.*
Bottom of cylindrical sinking head	46.7	45.5	−1.2
Neck, smallest part of casting	44.22	43.7	−0.52
In front of trunnions	52.71	53.75	+1.04
Maximum diameter below trunnions	56.75	−53.75	+3.00

* These numbers are only approximate, being taken with coarse shop calipers.

This shows that, if the mold was well rammed and accurate (which it apparently was), the casting contracted diametrally at all points except just above the trunnions, where it enlarged about an inch. This enlargement might have proceeded partly from the straining of the mold and partly from the rude method of measuring the casting. The diametral contraction was proportionally greater below the trunnions.

In regard to the amount of vertical contraction of the casting, no data is at hand by which it can be accurately determined. The vertical contraction was probably not far from one-eighth of an inch for every 16 inches of length in the casting, and as the mold for the casting was 462 inches in length, the vertical contraction would be about 3.6 inches.

13. *Longitudinal shrinkage strain.*

In my report to the Chief of Ordnance U. S. A., dated March 18, 1885, I stated that "the only rational explanation that suggests itself to me at this writing is that the great length of the casting would, in cooling, necessarily contract a good deal longitudinally (vertically), and the enlarged cylindrical sinking head at one end and the sloping body at the other acted like holders in a testing machine, and did not allow the metal to sink down, especially after setting on the exterior."

Mr. Alfred E. Watkins[*] says:

The difference in time required to cool the different parts of a casting depends upon their relative thickness * * *

The thickest part of a mass of molten metal always shrinks last; and, "as a rule, moldings should seldom be cast on a column," as they tend to weaken it. Again, Lieutenant Birnie, Ordnance Department, in speaking of the castings for the 2½-inch bronze life-saving guns,[†] says:

> With castings Nos. 1 and 2 (the latter of which was afterwards condemned) a pattern was used for molding the sand-head, which had become worn at the bottom by contact with the heated chill, and thus caused a shoulder to be formed in the mold at the base of the sand-head. The injurious effect of this was at once apparent in the castings, both of which were cracked around the chase just below the sand-head, the shoulder having acted to prevent the metal in the sand-head from sinking properly to supply the shrinkage below. A new pattern was at once substituted.

The case cited by Lieutenant Birnie, U. S. A., bears directly upon this question. If he found that the slight shoulder forming a neck at the top of a casting about 47 inches in length produced injurious strains sufficient to crack the chase, how much more would a shoulder at the base of the sinking head for a casting 462 inches in length be apt to produce injurious strains below the plane of the shoulder? Especially would this be true when the metal between this shoulder and the trunnions was delayed in its contraction and shrinkage by the fire and hot air around this portion of the flask, while the large bottom mass was cooling, contracting, and shrinking away from the half fluid metal in the chase.

Again, it is a well-known fact that "melted iron, when cooling, cools the fastest at the bottom of the mold and at the sides and cope surfaces, which draws molten iron from the hottest or central portion to supply the shrinkage of the cooling parts." This statement was apparently verified in this casting, which undoubtedly cooled more rapidly where walled up with brick and sand than it did about the chase, surrounded by a fire and hot air. That fluid iron was drawn from this region was shown by the less and less convexity of the fractured surfaces of the different sections as the bottom or breech was approached.

The convexity of the surfaces of fracture was, in every section except the one 58.75 inches from the bottom of the casting, turned toward the breech. This exception exhibited an irregular outline, and had a basin-shaped cavity on one side with its convexity towards the muzzle, which is attributed to the abnormal shrinkage strains caused by the fixed position of the trunnions, their inability to move downward, and the dependent weight of the breech.

Since the above was written I have run across a very similar case, cited by Captain (afterwards General) Rodman, in "Metals for Cannon," page 127, which, from its pertinence to this subject, I have transcribed entire:

> The above data show the metal in the West Point gun to be more dense, of much greater strength, more elastic, and much more incompressible than that in the Fort Pitt gun, and of almost equal ultimate extensibility; or that it is superior in every quality except one, and but slightly inferior in that. Yet the endurance of the Fort

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[*] Article on "Casting," in Appleton's "Cyclopædia of Mechanics," Vol. I, p. 336.
[†] Report of Chief of Ordnance U. S. A., 1884, p. 392.

Pitt gun was more than double that of the West Point gun. In other words, the *inferior* metal makes the *superior solid* cast gun.

Startlingly absurd as this conclusion appears, it is nevertheless true, and admits of satisfactory explanation, in strict accordance with the known properties of cast-iron.

The iron of which these guns were made was identical in quality when it went into the melting furnaces. The difference in quality, as found in the guns, was caused by the difference in treatment which it received in the furnaces, and by the different rates of cooling to which the guns were subjected after casting. The Fort Pitt furnaces have a stronger draft, melt quicker, and "work lower," or decarbonize their iron less, than the West Point furnaces.

The West Point gun mold was rammed up in green or moist sand to a point above the trunnions, that part of the mold containing the chase of the gun being entirely uncovered.

The Fort Pitt gun mold was placed in a closely covered pit, which had been previously heated by fire, and in which a moderate fire was burning at the time of casting, and continued to burn for some time after.

Green or moist sand is a very good conductor of heat, owing to the evaporation of the moisture which it contains. It is well known that a body will cool much more rapidly in the open air than in a closely covered pit, even without any application of heat from other sources.

There can be no doubt, therefore, that the West Point gun cooled more rapidly than the Fort Pitt gun, nor that it was composed of higher or more decarbonized iron. Now, it is well known that the higher the iron and the more rapidly it is cooled the greater will be its contraction in cooling.

It is equally well known that the greater the contraction of the iron the more liable is the casting to be strained in cooling; and in no case is this danger more imminent, or the strain produced more certain to be injurious, than in cooling from the exterior guns, hydraulic cylinders, &c., of large diameter. For (for the reasons given in my letter to Colonel Craig, hereto appended, page 93) the strain due to contraction in cooling is sure, in these cases, to act in concert with the bursting force.

There can be no doubt, therefore, that the superior qualities which the iron in the West Point gun has been shown to possess were more than neutralized in the gun by the greater strain to which it was subjected in cooling; but additional support of this conclusion is found in the less enlargement of the chamber of the West Point than that of the Fort Pitt gun, when first discovered to be cracked, in proportion to the ultimate permanent set which the iron would undergo from a state of perfect freedom from strain.

III.—PHYSICAL PROPERTIES.

1. *Initial tension.*

From the casting for the 12-inch tubed rifle, three initial tension rings will be taken, which will be marked respectively A, B, and C.

They will be taken as follows:

A, 30 inches from the muzzle.

B, 0 inch from the muzzle.

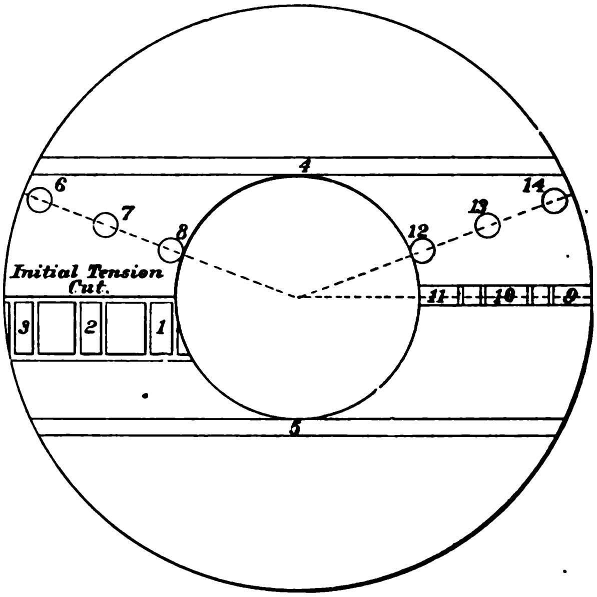
These two have already been cut from the casting.

C, 22 inches from the breech.

The specimens taken from these rings will be sent to Watertown Arsenal for test, and the results may be inserted hereafter in their proper place. The positions of the specimens in the rings are shown in diagram C. In order to lay before the Department the principal data relating to the initial tensions of the castings made here under this contract, for direct comparison, a tabular statement has been prepared and is appended, marked Table II.

DIAGRAM C.

[12-inch steel-tubed B. L. R. Second casting.]



Plan of initial tension rings from cast-iron body of 12-inch tubed rifle, showing position and nu of test specimens. Three disks: "A," taken 30 inches from muzzle of gun; "B," taken 0 inch muzzle of gun; "C," taken 22 inches from breech of casting.

2. TEST SPECIMENS.

[12-inch tubed rifle. Second casting.]

Number, kind, and dimensions of test specimens taken from each initial tension ring.

Number of specimens.	Kind.	How taken.	Where taken.		Size.	
			Number.	Position.	Length.	Diamete
					Inches.	
3	Tenacity	Tangentially	1 2 3	Inside Middle Outside	2.1	2" square.
3	Tenacity	Longitudinally	6 7 8	Outside Middle Inside	2.1	2" square.
3	Tenacity	Radially	9 10 11	Outside Middle Inside	2.1	2" square.
2	Tension	Tangentially	4 5	Both inside and on opposite sides of bore.	*20	1".75 squ
3	Hardness and specific gravity.	From face on a radius.	12 13 14	Inside Middle Outside	0.5	1".5.

* Between shoulders.

In addition to the above, the following specimens were taken for determining hardness and specific gravity, viz: Two specimens, A and B, were taken from opposite sides at the bottom of casting; three specimens, C, D, and E, from the trunnion section of the casting which was 22 inches in length, one each from inside, middle, and outside of cross-section, and three specimens, F, G, and H, from the section where the rupture of March 17 took place. (See diagram A.)

The specimens for hardness and density will be furnished at this foundry and sent to Watertown Arsenal for test. A table giving the results of the tests will be appended hereafter and marked Table III.

The tenacity and tension specimens will be planed to the dimensions given in the above table and then sent to Watertown to be tested after finish turning. The results from the tenacity specimens will be found in Table IV, to be appended later.

For the information of the Department and for comparison, a table giving the densities and tenacities of specimens taken from a 10-inch rifle cast for the Argentine Republic in 1872 or 1873. This gun (foundry No. 2341) was rejected on inspection for defects near the bottom of the bore, and in July, 1873, was cut up into sections, as shown in the sketch in the table giving the results of the tests (see Table V appended hereto). These results will be useful for comparison. The casting for this gun was about the same size as for a 15-inch Rodman smooth-bore gun.

TABLE I.—*Statement of fabrication of ordnance for the service of the United States by South Boston Iron Works, at the South Boston Foundry, under the supervision*† *of Capt. D. A. Lyle, Ordnance Department, U. S. Army.*

[Second casting for 12-inch wire-wrapped steel-tubed gun, cast December 23, 1884.]

CHARGE.

Richmond iron used.

Grade of iron.	Furnaces.			
	No. 1.	No. 2.	No. 3.	Total.
	Pounds.	*Pounds.*	*Pounds.*	*Pounds.*
No. 1				
No. 2	14,000	14,000	14,000	42,000
No. 3, hard*	24,000	24,000	24,000	72,000
No. 3, soft	17,000	17,000	17,000	51,000
Remelted	27,000	27,000	27,000	81,000
	82,000	82,000	82,000	246,000= 109.8 tons.

*Classed as "No. 4 Richmond" at this foundry.

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† The entire operation and superintendence of and responsibility for the casting was under the direction of the founders, and the only supervision exercised by the inspectors was that required by the contract, so far as it provides for inspections at every stage of the manufacture.

Coal consumed.†

"Pennsylvania gas coal" used.	Furnaces.			
	No. 1.	No. 2.	No. 3.	Total.
	Tons.	*Tons.*	*Tons.*	*Tons.*
Melting	12	12¼	12¼	36½
Fusion	3	2¾	2¾	8½
Total tons	15	15	15	45

† Estimated; assumed to be 1 ton per furnace per hour.

Character of test sticks.

Furnaces.	No. 1.	No. 2.	No. 3.	Basin.
Iron ...	White crystalline, slightly mottled.	Dark gray, earthy.	Grayish white crystallines, lightly mottled.	Gray, fine, granular.

RECORD OF CASTING.

Furnaces fired, December 22, at 8.45 p. m.

Metal down, December 23, at 8 a. m.

Time of melting, 11¼ hours.

Time in fusion, 3¼ hours.

Gun cast, December 23, at 11.15 a. m.

Time occupied in casting, 36 minutes.

Temperature of water entering core-barrel, 38 degrees.

Temperature of water leaving core-barrel, 71 degrees.

Rate of water per minute, 40 gallons.

Fire kindled in pit, December 23, at 11.29 a. m.

Fire in pit went out, December 24, 6 a. m.

Fire in pit burned 18½ hours.

Water shut off, December 24, at 10 a. m.

Core-barrel removed at 10.30 a. m.

Water entered gun at 11.30 a. m.

Rate of water per minute, 40 gallons.

Temperature of water entering gun, 38 degrees.

Temperature of water leaving gun in 27 minutes, 145 degrees.

Rate of water changed December 24, at 12 m., to 28 gallons.

Total time in cooling gun, 140 hours.

COOLING TABLES.

Core-barrel		Core-barrel removed.											
Hours.	Degrees.	Hours.	Degrees.	Hours.	Degrees.	Hours.	Degrees.	Hours.	Degrees.	Hours.	Degrees.	Hours.	Degrees.
1	71	23	‡62	45	111	67	74	89	58	111	47	133	42
2	71	24	(§§)	46	111	68	72	90	57	112	46	134	42
3	70	25	145	47	110	69	72	91	56	113	45	135	41
4	70	§26	154	48	109	70	72	92	55	114	44	136	41
5	70	27	160	49	108	71	72	93	54	115	44	137	41
6	69	28	156	50	107	72	72	94	54	116	44	138	40
7	68	29	153	51	106	73	72	95	54	117	44	139	40
8	67	30	150	52	104	74	71	**96	54	118	44	††140	40
9	66	31	143	53	102	75	70	97	54	119	44		
10	66	32	134	54	100	76	69	98	54	120	44		
11	66	33	129	55	98	77	68	99	53	121	44		
12	65	34	128	56	96	78	67	100	52	122	44		
13	65	35	126	57	95	79	66	101	52	123	Lost.		
14	65	36	124	58	93	80	65	102	51	124	44		
15	65	37	122	59	90	81	64	103	50	125	44		
16	64	38	120	60	88	82	64	104	50	126	44		
17	64	39	118	61	86	83	63	105	50	127	43		
18	64	40	116	62	84	84	62	106	50	128	42		
19	64	41	114	63	82	85	62	107	50	129	42		
20	63	42	113	64	80	86	61	108	50	130	42		
21	62½	43	112	65	78	87	60	109	49	131	42		
22	62	44	112	66	76	88	59	110	48	132	42		

** Water rate changed to 20 gallons per minute.

‡ Water shut off to remove core-barrel.

§§ Core arbor removed.

§ Water rate changed to 28 gallons per minute.

†† Water shut off, leaving bore filled with water.

TENSILE STRENGTH.

Specimens.	Diameter of specimen.	Area of cross-section.	Breaking weight.	Tenacity; pounds per square inch.
	Inches.	*Inch.*		
1	1. 129	1	29, 820	29, 820
2	1. 129	1	29, 410	29, 410
3	1. 129	1	33, 180	33, 180

INITIAL TENSION.

Distance from muzzle.	Exterior diameter of ring.	Interior diameter of ring.	Thickness of ring.	Thickness of broken section; mean.	Interior opening.	Exterior opening.	Circumference of exterior of ring.	Exterior per inch of circumference.
Inches.	*Inches.*	*Inches.*	*Inches.*	*Inch.*	*Inch.*	*Inch.*	*Inches.*	*Inch.*
30	45. 35	10. 95	3. 1	0. 31	0. 0365	0. 1185	142. 47+	. 00083174
0	46. 125	10. 95	3. 1	0. 41	0. 0325	0. 0975	144. 9	. 00067288

TABLE II.—***Tabular statement of initial tensions*** (***for comparison***).

Gun.	12-inch M. L. R. mortar.		Body, 10-inch wire-wrapped B. L. R.		12-inch cast-iron B. L. R	
Where taken.	Muzzle.	Experimental cylinder after unhooping.	Muzzle.	Breech.	Muzzle.	Breech.
	Inches.	*Inches.*	*Inches.*	*Inches.*	*Inches.*	*Inches.*
rior diameter of initial sion ring	32. 375	31. 0461	34. 125	31. 026	25. 76	57. 15
h of slot before rupture	0. 511	0. 5	0. 504	0. 506	0. 49	0. 5
:h of slot after rupture	0. 612	0. 571	0. 604	0. 567	0. 5	0. 6615
Difference	0. 101	0. 071	0. 101	0. 061	0. 01	0. 1615
nsion per linear inch of exior circumference	0. 000393	0. 0007279	0. 00094	0. 00061	0. 000123	0. 000899511
al tension (pounds)	15, 750	12, 000	16, 100	13, 125	3, 500	15, 750

Gun.	12-inch hooped and tubed B. L. R.		12-inch tubed B. L. R.		
			Muzzle.		Breech.
Where taken.	Muzzle.	Breech.	A. 30 inches from muzzle.	B. 0 inch from muzzle.	C. 22 inches from breech of casting and 4 inches in front of breech of gun.
	Inches.	*Inches.*	*Inches.*	*Inches.*	*Inches.*
rior diameter of initial ısion ring	39. 85	41. 3	45. 35	46. 125	56. 6
th of slot before rupture	0. 508	0. 5	0. 5075	0. 4985	0. 501
th of slot after rupture	0. 554	0. 5065	0. 626	0. 596	0. 656
Difference	0. 046	0. 0065	0. 1185	0. 0975	0. 155
nsion per linear inch of exior circumference	0. 000367434	0. 00005009	0. 00083174	0. 00067288	0. 00087109
al tension (pounds)	7, 000	2, 500	15, 500	13, 400	....

TABLE III.—*Densities and hardness.*

[Results from specimens taken from second casting for 12-inch tubed rifle, ruptured transversely March 17, 1885.]

Order from muzzle.	Position of specimens.					
	Inside.			Middle.		
	Marks.	Density.	Hardness.	Marks.	Density.	Hardness.
1	A 12	7.2821	17.90	A 13	7.3122	20.03
2	B 12	7.3526	19.18	B 13	7.3012	18.58
3	F	7.3503	19.81	G	7.3226	18.09
4	C	7.3707	20.47	D	7.2091	16.23
5	12 T C 12	7.3609	21.17	12 T C 13	7.3636	17.19
Mean		7.34332+	19.706		7.30174	18.024

Order from muzzle.	Position of specimens.				
	Outside.			Mean.	
	Marks.	Density.	Hardness.	Density.	Hardness.
1	A 14	7.2761	17.53	7.29013+	18.486+
2	B 14	7.3218	17.53	7.3252	18.43
3	H	7.3423	17.90	7.3384	18.60
4	E	7.3312	19.18	7.30366+	18.626
5	12 T C 14	7.3483	17.53	7.3576	18.896+
6	A B	7.3115 7.2949	16.90 16.31	7.3032	16.605
Mean		7.31801+	17.554	7.319698	18.0971+

From whence taken.

No. 1. Initial tension ring A, 30 inches above muzzle.
No. 2. Initial tension ring B, 0 inch from muzzle.
No. 3. First ruptured section (March 17, 1875), 147 inches above axis of trunnions, or 287 inches f breech.
No. 4. Trunnion section (rear end). Axis of trunnions 140 inches from breech.
No. 5. Initial tension ring C, 22 inches from breech, or 4 inches above rear face of breech of gun.
No. 6. Bottom of breech. From exterior at opposite ends of the same diameter.

TABLE IV.—*Tenacity specimens taken from the second (or ruptured) casting for the 12-i breech-loading rifle, lined with wire-wrapped steel tube.*

From whence taken.	Taken tangentially.				Position of initial te sion ring.
	No. 1 (inside), in pounds per square inch.	No. 2 (middle), in pounds per square inch.	No. 3 (outside), in pounds per square inch.	Mean, in pounds per square inch.	
Intial tension ring A:* Specimens marked A and numbered as shown in table.	29,820	29,410	33,180	30,803	30 inches from mu
Initial tension ring B:* Specimens marked B and numbered as shown in table.	30,280	28,900	29,850	29,6766+	0 inch from muzzle.
Initial tension ring C:* Specimens marked C and numbered as shown in table.	....	....	....	....	22 inches from bre

* Record of tests not yet received.

TABLE IV.—*Tenacity specimens taken from the second casting, &c.*—Continued.

From whence taken.	Taken longitudinally.				Position of initial tension ring.
	No. 8 (inside), in pounds per square inch.	No. 7 (middle), in pounds per square inch.	No. 6 (outside), in pounds per square inch.	Mean, in pounds per square inch.	
Initial tension ring A:* Specimens marked A and numbered as shown in table.	31, 350	28, 400	34, 820	31, 5233	30 inches from muzzle.
Initial tension ring B:* Specimens marked B and numbered as shown in table.	33, 700	†23, 620	32, 680	30, 000	0 inch from muzzle.
Initial tension ring C:* Specimens marked C and numbered as shown in table.	....	....	....	....	22 inches from breech.

From whence taken.	Taken radially.				Position of initial tension ring.
	No. 11 (inside), in pounds per square inch.	No. 10 (middle), in pounds per square inch.	No. 9 (outside), in pounds per square inch.	Mean.	
Initial tension ring A:* Specimens marked A and numbered as shown in table.	26, 940	†26, 150	30, 620	27, 903+	30 inches from muzzle.
Initial tension ring B:* Specimens marked B and numbered as shown in table.	29, 700	27, 700	31, 080	29, 473	0 inch from muzzle.
Initial tension ring C:* Specimens marked C and numbered as shown in table.	....	....	....	....	22 inches from breech.

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* Appearance of fracture, "granular, mottled, resembling granite."

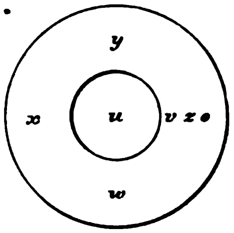
† Major Parker reports these specimens as showing "very marked contrast between light and dark colored metal."

TABLE V.—*Physical properties of 10-inch rifle, foundry No. 2341, made for the Argentine Republic by the South Boston Iron Company, and cut up for test July 3, 1873, after its rejection.*

Number of section.	Distance from muzzle.	Specimen.						Mean.	
		No. 1, inside.		No. 2, middle.		No. 3, outside.			
		Density.	Tenacity.	Density.	Tenacity.	Density.	Tenacity.	Density.	Tenacity.
2	162 inches	7. 3361	32, 708	7. 3078	33, 279	7. 2864	31, 490	7. 3101	32, 492
3	147 inches, rear	7. 2970	33, 134	7. 2345	32, 044	7. 1966	23, 528	7. 2427	29, 568+
3	132 inches, front	7. 3184	36, 292	7. 3003	31, 547	7. 2911	32, 349	7. 3032+	33, 396
4	No specimens taken	....	....	....	....	....	....	....	....
5	98 inches, rear	7. 2535	27, 155	7. 2818	31, 469	7. 2849	31, 833	7. 2734	30, 152+
6	67.5 inches, rear	7. 3026	29, 344	7. 2519	27, 732	7. 1870	24, 492	7. 2471+	27, 189+
7	30 inches, rear	7. 3023	35, 064	....	....	7. 2004	25, 969	7. 2640	30, 514
	0 inches, middle of face	....	....	7. 2492	26, 130	....	....		
	2 inches, porous spot	....	....	....	....	7. 3043	34, 892		
	Means	7. 3016	32, 283	7. 2709	30, 367	7. 2501	29, 222	7. 2742	30, 624

* Record of tests not yet received.

SECTION I.—BREECH SECTION.

Positions of specimens.	Marks on specimen.	Density.	Tenacity.
 x y u v z o w Diagram of face toward the muzzle.	U	7.1833	30,725
	V	7.2725	27,661
	W	7.3201	34,283
	X	7.3172	33,257
	Y	7.2711	29,299
	Z	7.3257	35,155
	0	No record found.	
	Mean...	7.28165	31,730

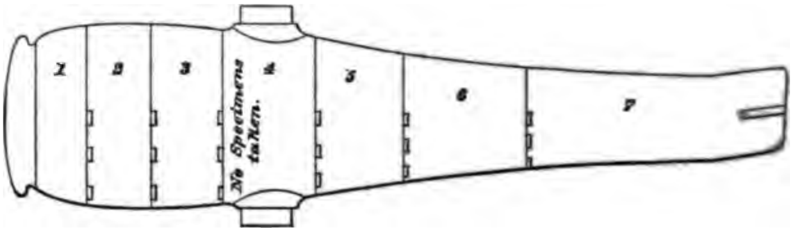
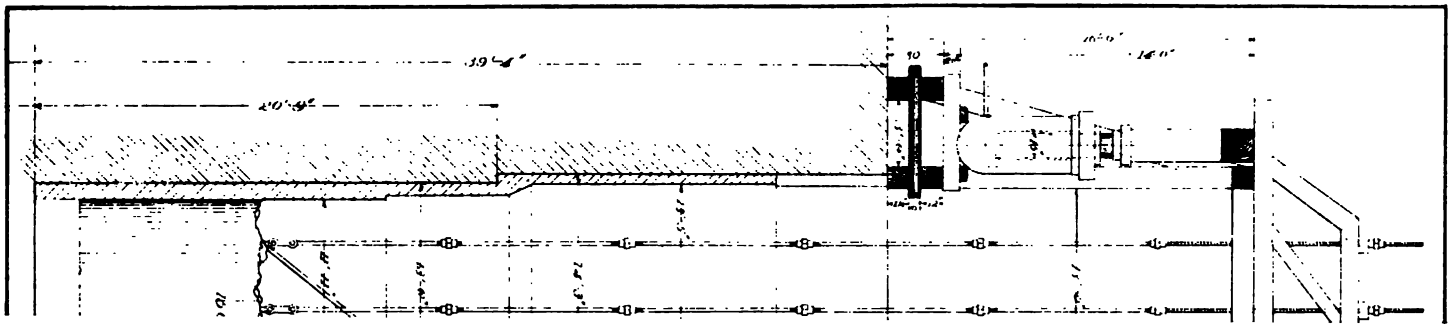


Diagram of 10-inch rifle, showing method of cutting up and taking specimens.



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APPENDIX 33.

HE SHRINKAGES AND THEORETICAL RESISTANCE OF 8-INCH EXPERIMENTAL STEEL BREECH-LOADING RIFLE NO. 1, DOUBLE-HOOPED.

BY LIEUT. ROGERS BIRNIE, JR., ORDNANCE DEPARTMENT, U. S. ARMY.

(1 plate.)

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ormulæ: For application with four concentric cylinders.
  For application with three concentric cylinders.
  For application with two concentric cylinders.
ection of the powder chamber:
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  Second method of solution—state of rest considered.
ection of trunnion hoop.
ection between powder chamber and trunnion hoop.
ection over breech of tube.
ection of the breech (screw recess).
ffect of the single hoop A_{13}.
ection through base of hoop A_1.
ection through shoulder on jacket.
ection through front (within face) of jacket.
ection through middle of D row of hoops.
ection through base of C row of hoops.
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esistance of unhooped portion of gun.
ummary table of values of constants and results of computations.
ongitudinal resistance.
  Section over breech of tube.
hanges in length of tube and jacket due to shrinkage.

The shrinkages to be used in the actual construction of this gun form he principal part of the subject, these shrinkages being so arranged as o give a maximum value for the resistance of the gun to an interior ressure, except at certain points within the length of the hooping here a satisfactory resistance, less than the theoretical maximum, may e utilized, and where this factor becomes subservient to other necessary onsiderations involved in the construction.

We begin with the gun already designed,* and having the form and imensions given in the figure. (See plate.) The computations herewith depend upon those fixed dimensions and the constant values repesenting the physical qualities which have been determined for the etals to be used in the construction of the gun by extended tests of pecimens taken from the steel forgings. For a complete adjustment f the shrinkages it has been thought proper to discuss their values in en sectional planes (see plate) intersecting the axis of the bore at right angles through the hooped portion of the gun. The section of the powder chamber, being the most important, is first considered, and the remaining sections are taken up in the order given hereafter.

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* The design of this gun was completed in the Bureau of Ordnance, under the direction of the Chief of Ordnance, U. S. Army.

Advantage is taken of the practical knowledge obtained in the experimental hooping test of a compound cylinder representing the chamber section of this gun (see Notes on the Construction of Ordnance, No. 32), namely, the formulas here used are the same as those which gave such satisfactory results in that test; and, having in view the degradation of the physical qualities of the hoop metal subsequent upon that test, we here use appropriately reduced values from those representing the extreme elastic properties of the hoop metals, and make a greater reduction for the outside hoops than for those which have an exterior support in the structure.

The methods of computation used are an extension of those given in Notes on the Construction of Ordnance, No. 31. Wishing, however, to avoid the intricate solution of the problem for "finding the maximum pressure that can be supported (and all the conditions of state) in a gun assembled (or assumed to have been assembled) with arbitrary shrinkages," as given in Part II of that Note, we have here been enabled to substitute abridged methods of solution by considering primarily the *state of the system at rest.* This is the state of the system which is actually involved in the construction of the gun, and through the formulas given, supposing a given compound cylinder actually assembled with known shrinkages, we may, by measuring the actual compression of the bore of tube from the original, arrive at a complete solution of the condition of the system for any state whatever. Readily obtainable data is thus made available, which is not so if the theoretical discussion be limited to a consideration of the state of action. The pressures incident to the state of action are available only to be considered as theoretical values which should produce a certain theoretical effect. We assume always that the theory is true, but we now wish to abridge the methods of computation, and at the same time base them upon data which becomes of practical application in the case of a gun or compound cylinder already assembled.

The discussions will be found strictly confined to the principles enunciated by Clavarino, page 7, Notes on the Construction of Ordnance, No. 6, viz: "The cylinder must be considered as having reached the limit of elasticity when, from the effects of all the forces acting upon any one of its fibers, it undergoes an elongation or a contraction equal to that which takes place in the mechanical tests respectively of traction and compression;" that is to say, the forces acting upon the elementary cylinders composing a section of the gun will be limited so that their combined effect shall not produce an elongation or contraction of any fiber in excess of the safe limits determined for such displacements by the mechanical tests of the metal. The system will therefore be arranged to work within the elastic limit of the elementary cylinder which is most severely strained in each separate section. In this gun the tube will be found to constitute the vital cylinder (as regards tangential resistance) until we pass forward into the D and C rows of hoops, where the hooping becomes relatively light for the tube and the tangential resistance of the gun becomes dependent upon a suitable working tension for the outside row of hoops. Throughout the whole of the hooped portion of the gun the tube will be found theoretically weakest under radial compression; that is, it will reach the elastic limit in this direction before the full elastic tangential extension of the cylinder is developed. The same is true of the jacket except for the threaded portion near its muzzle end, whilst on the other hand the safety limit for all the hoops is first reached under the tangential tension to which they will be subjected with the system in action.

FORMULAS.

Taking the general case of four cylinders, if the system be considered in *action*, the pressures which determine the elastic limit of the separate elementary cylinders in the combined system will be derived from the following (see formulas [27] Notes on the Construction of Ordnance, No. 7):

$$(1)\ \ldots \left\{\begin{aligned}
&\left.P_3 \ =\frac{3\,(R_4^2-R_3^2)\,\theta_3}{4\,R_4^2+R_3^2}\right\}\text{for the fourth cylinder.}\\
&\left.\begin{aligned}
P_2^{(1)}&=\frac{3\,(R_3^2-R_2^2)\,\theta_2+5\,R_3^2\,P_3}{4\,R_3^2+R_2^2}\\
P_2^{(2)}&=\frac{3\,(R_3^2-R_2^2)\,\rho_2+3\,R_3^2\,P^3}{4\,R_3^2-R_2^2}
\end{aligned}\right\}\text{for the third cylinder.}\\
&\left.\begin{aligned}
P_1^{(1)}&=\frac{3\,(R_2^2-R_1^2)\,\theta_1+5\,R_2^2\,P_2}{4\,R_2^2+R_1^2}\\
P_1^{(2)}&=\frac{3\,(R_2^2-R_1^2)\,\rho_1+3\,R_2^2\,P_2}{4\,R_2^2+R_1^2}
\end{aligned}\right\}\text{for the second cylinder.}\\
&\left.\begin{aligned}
P_0^{(1)}&=\frac{3\,(R_1^2-R_0^2\ \theta_0+5\,R_1^2\,P_1}{4\,R_1^2+R_0^2}\\
P_0^{(2)}&=\frac{3\,(R_1^2-R_0^2)\,\rho_0+3\,R_1^2\,P_1}{4\,R_1^2-R_0^2}
\end{aligned}\right\}\text{for the first cylinder.}
\end{aligned}\right.$$

The system being supposed assembled, the values for variations of the pressures, or for the transmitted pressures which vary in unison, will be derived from the following general equations of equilibrium here reduced to their simplest forms [see formulas, page 18, Note 7]:

$$(2)\left\{\begin{aligned}
p_3&=\frac{5\,R_2^2\,E_3\,(R_4^2-R_3^2)}{E_3\,(R_4^2-R_3^2)\,(4\,R_2^2+R_3^2)+E_2\,(R_3^2-R_2^2)\,(4\,R_4^2+R_3^2)}p_2=ap_2\\
p&=\frac{5\,R_1^2\,E_2\,(R_3^2-R_2^2)}{E_2(R_3^2-R_2^2)4\,R_1^2+R_2^2)+E_1(R_2^2-R_1^2)[(4R_3^2+R_2^2)-5\,R_3^2a]}p_1=bp_1\\
p_1&=\frac{5\,R_0^2\,E_1\,(R_2^2-R_1^2)}{E_1(R_2^2-R_1^2)\,(4R_0^2+R_1^2)+E_0(R_1^2-R_0^2)[(4\,R_2^2+R_1^2)-5\,R_2^2b]}p_0=cp_0
\end{aligned}\right.$$

If in the last of the above equations we substitute $p_0=-P_0$, or the value of the internal pressure derived from formulas (1), we will obtain the relief of pressure on exterior of tube upon the supposition that the system has been assembled with shrinkages computed from the set of values P_0, P_1, P_2, and P_3, and that the state of action has been changed to that of rest. The pressure on exterior of tube for the state of rest or *the initial compression* is then given by the algebraic sum P_1+p_1, in which—

$$(3)\ \ldots\ldots\ldots\ \ p_1=c-P_0$$

The elastic limit of the tube in the state of rest will be exceeded if that sum is greater than

$$(4)\ \ldots\ldots\ldots\quad (P_1+p_1)=\frac{3\,(R_1^2-R_0^2)\rho_0}{5\,R_1^2}$$

and in that case the shrinkage values above indicated would be too great, and the original values P_0, P_1, &c., may not be taken.

The value for the internal pressure which will preserve unimpaired the elasticity of the tube, both for the state of action and of rest, will be obtained from the following:*

$$(5)\ \ldots\ldots\quad P_0=\frac{24\,R_1^2\,(R_1^2-R_0^2)\,\rho_0}{5\,R_1^2\,[(4\,R_1^2-R_0^2)-3\,R_1^2c]}$$

and the dependent value for P_1 from the following [equation (4) Part 1, Note 31]:

$$(6)\ \ldots\ldots\quad P_1=\frac{3\,(R_1^2-R_0^2)\,\rho_0+5\,R_1^2\,c\,P_0}{5\,R_1^2}$$

Equation (5) may be used for determining the limiting value of the internal resistance whenever the tube constitutes the vital cylinder, *i. e.*, when the elastic resistance of the gun section is limited by that of the tube. And such value of P_0 with the dependent value of P_1 from equation (6) will be used as the adjusted values for these pressures with the system in action. The original values for P_2 and P_3 may or may not be readjusted, depending upon circumstances. They cannot, however, be increased, since they represent the maximum values possible for those pressures.

For the special case where the initial compression of the tube for the system at rest is given, the value for the internal pressure, which will determine the elastic strength of the tube for the state of action, will be derived as follows: Designating this pressure by P_1', we have from equation (3)

$$P_1^{11}=P_1+p_1=P_1-c\,P_0$$

from which

$$(7)\ \ldots\ldots\ldots\ldots\quad P_1=P_1'+c\,P_0$$

which being combined with the last of equations (1) gives:

$$(8)\ \ldots\ldots\ldots\quad P_0=\frac{(3\,R_1^2-R_0^2)\,\rho_0+3\,R_1^2\,P_1'}{(4\,R_1^2-R_0^2)\,3-R_1^2c}$$

in which P_1' is equal to P_1+p_1. But the value of the internal resistance thus determined may be found incompatible with the safety of one or more of the outer cylinders, and in that case will require further modification.

The initial compression of the system refers to the values of the several normal pressures in the state of rest.

Call

$$P_1+p_1=P_1' \qquad P_2+p_2=P_2' \qquad P_3+p_3=P_3'$$

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* The equation is derived by combining the value of P_1 from equation (4) with same from equation (3), Note 31; it presupposes that the tube will fail under radial compression.

The values of P_0, P_1, P_2, and P_3 being known, those of P_1', P_2', and P_3' will be derived as follows:

$$(9) \quad . \; . \; . \quad p_1 = -c\,P_0 \qquad p_2 = -bp_1 \qquad p_3 = -ap_2$$

$$(10) \quad . \; . \quad P_1' = P_1 + p_1 \qquad P_2' = P_2 + p_2 \qquad P_3' = P_3 + p_3$$

Or, conversely, if we have given the values P_1', P_2', and P_3', those of P_1, P_2, and P_3 will be derived by the use of equations (9) in connection with—

$$(11) \quad . \quad P_1 = P_1^1 - p_1 \qquad P_2 = P_2' - p_2 \qquad P_3 = P_3' - p_3$$

The shrinkages will be the same whether computed by the values of the pressures incident to the state of action or those belonging to the state of rest; the use of the latter, however, abbreviates the work and enables one to make a more ready adjustment of the shrinkage values in case of necessity.

To compute the shrinkages from the pressures incident to the state of action, we have the following formulas:

$$(12) \quad . \quad \varphi_1 = \frac{(4\,R_0^2 + R_1^2)\,P_1 - 5\,R_0^2\,P_0}{3\,(R_1^2 - R_0^2)\,E_0} + \frac{(4\,R_2^2 + R_1^2)\,P_1 - 5\,R_2^2\,P_2}{3\,(R_2^2 - R_1^2)\,E_1}$$

$$(13) \quad . \quad \varphi_2 = \frac{(4\,R_1^2 + R_2^2)\,P_2 - 5\,R_1^2\,g}{3\,(R_2^2 - R_1^2)\,E_1} + \frac{(4\,R_3^2 + R_2^2)\,P_2 - 5\,R_3^2\,P_3}{3\,(R_3^2 - R_2^2)\,E_2}$$

in which

$$(14)\; g = -p_1 = \frac{5\,R_0^2\,E_1\,(R_2^2 - R_1^2)\,P_0 + 5\,R_2^2\,E_0\,(R_1^2 - R_0^2)\,P_2}{E_0\,(R_1^2 - R_0^2)\,(4\,R_2^2 + R_1^2) + E_1\,(R_2^2 - R_1^2)\,(4\,R_0^2 + R_1^2)}$$

$$(15) \quad . \; . \; . \quad \varphi_3 = \frac{(4\,R_2^2 + R_3^2)\,P_3 - 5\,R_2^2 f}{3_0\,(R_3^2 - R_2^2)\,E_2} + \frac{4\,(R_4^2 + R_3^2)\,P_3}{3\,(R_4^2 - R_3^2)\,E_3}$$

in which

$$(16)\; f = -p_2 = \frac{5\,R_1^2\,E_2\,(R_3^2 - R_2^2)\,d + 5\,R_3^2\,E_1\,(R_2^2 - R_1^2)\,P_3}{E_1 (R_1^2 - R_1^2)\,(4 R_3^2 + R_2^2) + E_2\,(R_3^2 - R_2^2)\,[(4\,R_1^2 + R_2^2) - 5\,R_1^2 a'}$$

with

$$(17) \quad . \; . \; . \; . \quad \begin{cases} d = \dfrac{5\,R_0^2\,E_1\,(R_2^2 - R_1^2)\,P_0}{E_0\,(R_1^2 - R_0^2)\,(4\,R_2^2 + R_1^2) + E_1\,(R_2^2 - R_1^2)(4\,R_0^2 + R_1^2)} \\ a' = \dfrac{5\,R_2^2\,E_0\,(R_1^2 - R_0^2)}{E_0 (R_1^2 - R_0^2)(4\,R_2^2 + R_1^2) + E_1\,(R_2^2 - R_1^2)\,(4 R_0^2 + R_1^2)} \end{cases}$$

The second members of equations (12), (13), and (15) may be replaced collectively or separately by the respective quantities $\frac{\theta_1}{E_1}$, $\frac{\theta_2}{E_2}$, and $\frac{\theta_3}{E_3}$, if we use the values P_3, $P_2^{(1)}$, and $P_1^{(1)}$, or either of them as originally deduced by the application of formulas (1) (see middle of page 5, Notes on the construction of Ordnance, No. 7).

To compute the shrinkages from the pressures incident to the state of rest, we have the following formulas:

$$(18) \quad . \; . \quad \varphi_1 = \frac{(4\,R_0^2 + R_1^2)\,P_1'}{3\,(R_1^2 - R_0^2)\,E_0} + \frac{(4\,R_2^2 + R_1^2)\,P_1' - 5\,R_2^2 P_2'}{3\,(R_2^2 - R_1^2)\,E_1}$$

$$(19) \quad . \quad \varphi_2 = \frac{(4\,R_1^2 + R_2^2)\,P_2' - 5\,R_1^2\,p_1'}{3\,(R_2^2 - R_1^2)\,E_1} + \frac{(4\,R_3^2 + R_2^2)\,P_2' - 5\,R_3^2\,P_3'}{3\,(R_3^2 - R_2^2)\,E_2}$$

in which

$$(20)\ .\ p_1'=\frac{5\,R_2^2\,E_0\,(R_1^2-R_0^2)}{E_0\,(R_1^2-R_0^2)\,(4\,R_2^2+R_1^2)+E_1\,(R_2^2-R_1^2)\,(4\,R_0^2+R_1^2)}P_2'$$

$$(21)\ .\ .\ .\ .\ \varphi_3=\frac{(4\,R_2^2+R_3^2)\,P_3'-5\,R_2^2p_2'}{3\,(R_3^2-R_2^2)\,E_2}+\frac{(4\,R_4^2+R_3^2)\,P_3'}{3\,(R_4^2-R_3^2)\,E_3}$$

in which

$$(22)\ p_2'=\frac{5\,R_3^2\,E_1\,(R_2^2-R_1^2)}{E_1(R_2^2-R_1^2)(4\,R_3^2+R_2^2)+E_2(R_3^2-R_2^2)\,[(4\,R_1^2+R_2^2)-5\,R_1^2b']}P_3'$$

and in this b' is the equivalent of the fractional coefficient of P_2' in equation (20).

In the above equations the shrinkages, represented by φ_1, φ_2, and φ_3 may be considered as the unknown quantities, or if they be given with any one of the remaining quantities P_1', P_2', P_3', p_1', or p_2'; these latter, supposed unknown, may all be determined.

Through this method, if we have given the shrinkages actually used in the construction of a gun, and have measured the compression of the bore, a complete analytical discussion of the construction may be made. The equation involving the compression of the bore enables us to deduce the value of P_1'; thus if in equation (4) we place

$$\rho_0=\frac{\varDelta R_0}{R_0}\div E_0 \text{ and } (P_1+p_1)^{(1)}=P_1'.$$

we find

$$(23)\ .\ .\ .\ .\ .\ .\ .\ P_1'=\frac{3\,(R_1^2-R_0^2)\,E_0}{5\,R_1^2}\ \frac{\varDelta R_0}{R_0}$$

Then equations (18) to (22), the values of P_2' and P_3', may be deduced, and with these, through equations (8), (9), and (11), we may pass to the values of the pressures that the system will support in action.

The tangential compression of the bore is an important factor in the adjustment of the shrinkages. Knowing the physical qualities of the tube metal, and guided by other considerations, we can in general assume an appropriate value for this factor in a theoretical discussion and thence derive the value of P_1' from equation (23). We may thence proceed to determine the appropriateness of any given set of shrinkages to the section of the gun under consideration, as in the practical method described above. In the gun of which we treat, for example, we wish to preserve the shrinkages for each cylinder or row of hoops as nearly alike as possible for given lengths, although the radii of the elementary cylinders in the sections considered may be different; again, whilst admitting all possible tangential compression of the bore in the section of the powder chamber, we wish this compression to show a curve of gradual decrease from the chamber section forward until it passes to nothing upon emerging from under the hooped portion of the gun.

If P_1', the exterior pressure upon the tube, be given, the tangential compression of the bore for the state of rest becomes known from the following equation, derived from (23), viz:

$$(24)\ .\ .\ .\ .\ .\ .\ .\ \frac{\varDelta R_0}{R_0}=\frac{5\,R_1^2\,P_1'}{3\,(R_1^2-R_0^2)\,E_0}$$

With P_0 and P_1 known, the tangential extension of the bore for the state of action will be derived from the following (page 13, Notes on the Construction of Ordnance, No. 6):

$$(25) \quad . \; . \; . \; . \; . \quad \frac{\varDelta R_0}{R_0}=\frac{(4\ R_1^2+R_0^2)\ P_0-5\ R_1^2\ P_1}{3\ (R_1^2-R_0^2)\ E_0}$$

and the radial compression of the wall of tube by means of the following (page 14, same Note):

$$(26) \quad . \; . \; . \; . \; . \quad \frac{d\ \varDelta R_0}{d\ R_0}=\frac{(4\ R_1^2-R_0^2)\ P_0-3\ R_1^2\ P_1}{3\ (R_1^2-R_0^2)\ E_0}$$

To deduce the working tension of the outer hoop when P_3 is known, we have, from the first of formula (1), the following:

$$(27) \quad . \; . \; . \; . \; . \; . \; . \; . \; . \quad \theta_3=\frac{(4\ R_4^2+R_3^2)\ P_3}{3\ (R_4^2-R_3^2)}$$

The corresponding tangential tension will be proportional to the safe tension and corresponding extension as originally determined by the tests of detached specimens.*

If the shrinkages are computed by formulas (12) to (17) inclusive, which apply to the state of action, we will obtain from the two terms which compose the second members of equations (12), (13), and (15) the numerical values of the displacements of metal which occur at the contact surfaces of the elementary cylinders for the *state of action;* the first term stands for the tangential compression of the exterior surface of the inner cylinder (an extension if the value is negative) and the second term for the tangential extension of the interior surface of the outer cylinder, On the other hand, if we compute the shrinkages by formulas (18) to (22) inclusive, which apply to the state of rest, the numerical values of the two terms which compose the second members of equations (18), (19), and (21) will represent the corresponding displacements of metal for the *state of rest.* Each shrinkage is, in either case, equivalent to the algebraic sum of the displacements named, and such algebraic sum is theoretically the same whatever may be the state of the system considered. Again, the second terms of the equations named may be used separately to find the state of strain existing at the interior surface of any one of the elementary cylinders either for the state of action or of rest.

APPLICATIONS.

Section over powder chamber.

$\rho_0=\theta_0=22.143$ $\rho_1=\theta_1=20$ $\theta_2=24.28$ $\theta_3=22.32$
$\varepsilon_0=0.0016$ $\varepsilon_1=0.001445$ $\varepsilon_2=0.0017$ $\varepsilon_3=0.0015625$
$E_0=E_1=13{,}840$ $E_2=E_3=14{,}286$
$R_0=4.75$ $R_1=7.0$ $R_2=11$ $R_3=13.15$ $R_4=15.75$

First values for the normal pressures, system in action.—By applying formulas (1) we obtain:

$P_3\ =\ 4.3185$ tons per square inch.
$P_2^{(1)}=\ 9.2492$ tons per square inch.
$P_1^{(2)}=17.6493$ tons per square inch.
$P_0^{(3)}=25.0843$ tons per square inch.

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* The preceding formulas apply generally to a compound cylinder composed of four elementary cylinders, but the system of notation employed admits of their ready application to a smaller number.

Values for variations of pressure, system assembled.—By applying formulas (2) we obtain:

$$p_3=ap_2;\ \log.\ a=(9.6167878)^{*}$$
$$p_2=bp_1;\ \log.\ b=(9.4215663).$$
$$p_1=cp_0;\ \log.\ c=(9.6109467).$$

Trial value for initial compression of tube.—By applying formulas (3) and (4) successively we find:

$$p_1=-c\ P_0=-10.2414 \text{ tons}$$
$$P_1+p_1=17.6493-10.2414=7.408$$
$$(P_1+p_1)^{(1)}=7.168.$$

Hence, the excess of the pressure upon the tube system at rest would be 0.24 of a ton per square inch if we should adopt the first values of P_0, P_1, P_2, and P_3, as above.

Safe value for the internal pressure.—Applying formula (5), we obtain a value for P_0 which will insure the safety of the tube for all states of the system, viz:

$$P_0=24.7741$$

and the dependent value of P_1 from equation (6) becomes:

$$P_1=17.2827.$$

The original value of P_2 and P_3 being safe for the hoops, we may preserve them, remarking, however, that the effect of this will be to increase the relative value of the two outer shrinkages (P^0 and P_1 having been reduced), but the resistance of the jacket cylinder to compression will be called into play to protect the tube from overcompression in the state of rest.

The shrinkages computed for the state of action.—Using the values for the pressures indicated above and applying formulas (12) to (17), inclusive, in which, since P_2 and P_3 retain their original values, we may replace the second members of equations (13) and (15) by $\frac{\theta_2}{E_2}$ and $\frac{\theta_3}{E_3}$ respectively, we find:

$$\varphi_1=-0.00035368+0.00120962=0.00085594$$

$\log.\ g=(1.1607037)$

$$\varphi_2=-0.00020576+0.0017=0.001494$$

$\log.\ a'=(9.8216482)$; $\log.\ d=(0.9213601)$; $\log.\ f=(0.7532028)$

$$\varphi_3=-0.00026534+0.0015625=0.0012972$$

Pressures incident to the state of rest.—We retain the last-named values for P_0, P_1, P_2, and P_3, and by applying formulas (9) find:

$$p_1=-10.1145 \qquad p_2=-2.67 \qquad p_3=-1.10484.$$

and from formulas (10):

$$P_1'=P_1+p_1=17.2827-10.1145=7.1682$$
$$P_2'=P_2+p_2=9.2492-2.67=6.5792$$
$$P_3'=P_3+p_3=4.31864-1.10484=3.21362$$

The value of P_1' representing the pressure acting on the exterior of the tube is, as it should be, the same as the value of $(P_1+p_1)^{(1)}$ derived by applying equation (4).

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[*] To abbreviate the work, the values of quantities will frequently be expressed by their logarithms written in brackets.

The shrinkages computed for the state of rest.—Substituting the values found for P_1', P_2', and P_3' in equations (18) to (22), inclusive, and reducing, we find:

$$\varphi_1=+0.00090939-0.00005345=0.00085594$$

log. $p_1'=(0.6398213)$.

$$\varphi_2=+0.000340073+0.00115416=0.001494$$

log. $b'=(9.8216482)$; log. $p_2'=(0.4764026)$.

$$\varphi_3=+0.0001344+0.0011628=0.0012972$$

or the values for the shrinkages are identical with those obtained by the preceding method.

To illustrate the significance of the numerical values composing the two terms of each of the shrinkage values as before indicated, we may write from them the following, which represent the tangential displacements of the fibers of metal expressed in thousandths per linear unit:

	System at rest.	System in action.
At exterior of tube	−0.90939	+0.35368
At interior of jacket	−0.05345	+1.20962
At exterior of jacket	−0.340073	+0.20576
At interior of inner hoop	+1.15416	+1.70
At exterior of inner hoop	−0.1344	+0.26534
At interior of outer hoop	+1.1628	+1.5625

The negative values represent compressions and the positive values extensions;* where the sign of the first term in the values (φ) was positive it becomes changed to negative and the reverse.

Action of the bore of tube.—We have $P_1'=7.168$ tons, and by formula (24) find that the tangential compression of the bore in the state of rest is:

$$\frac{\varDelta R_0}{R_0}=-0.0016$$

or the same value as that which we have assumed to be safe.

For the state of action with $P_0=24.774$ and $P_1=17.283$, the tangential extension of the bore derived from equation (25) is:

$$\frac{\varDelta R_0}{R_0}=0.0010754$$

Finally, for the radial compression of the wall of the tube in the state of action, equation (26) gives:

$$\frac{d\varDelta R_0}{d\,R_0}=-0.0016$$

which is again the same value as that assumed to be safe from the results of tests of detached specimens of the metal, and we perceive that the system is arranged to work so that the tube is compressed to its elastic limit in the state of rest, and in the state of action will be able to support an interior pressure of 24.774 tons per square inch without

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*The above values represent the actual changes from original dimensions, except for the exterior of jacket and inner hoop, for which the values represent the changes from dimensions "prepared for shrinkage." To obtain the actual state of change from the original for these two exterior surfaces we must take into consideration the *extension* induced by the original assemblage of each of those cylinders.

passing its elastic limit. Under the same circumstances, also, the elastic limit of none of the remaining elementary cylinders will be exceeded, as is shown by the tabulated values preceding. If we wished to examine the action of the jacket in respect to radial compression, system in action, equation (26) would be applied with the proper changes of notation, but in this gun the jacket will not be endangered in that way.

Section under trunnion hoop.

$\rho_0=\theta_0=22.143$ $\rho_1=\theta_1=20$ $\theta_2=24.28$ $\theta_3=16.0$

$\varepsilon_0=0.0016$ $\varepsilon_1=0.001445$ $\varepsilon_2=0.0017$ $\varepsilon_3=0.0014933$

$E_0=E_1=13{,}840$ $E_2=14{,}286$ $E_3=10{,}714$

$R_0=4.0$ $R_1=7.0$ $R_2=11.0$ $R_3=13.15$ $R_4=16.38$

First values for the normal pressures, system in action.—By formulas (1):

$P_3 = 3.674$ tons per square inch.
$P_2^{(1)}= 8.5632$ tons per square inch.
$P_1^{(2)}=17.07685$ tons per square inch.
$P_0^{(2)}=26.1247$ tons per square inch.

Variations of pressures, system assembled.—By formulas (2):

$p_3=ap_2$ log. $a=(9.5882426)$
$p_2=bp_1$ log. $b=(9.4074906)$
$p_1=cp_0$ log. $c=(9.4460755)$

Trial value for initial compression of tube.—By formulas (3) and (4):

$p_1=-c\,P_0=-7.2967$ $P_1+p_1=17.07685-7.2967=9.78$

$(P_1+p_1)^{(1)}=8.9475$

hence, the dangerous excess is equal to 0.8325 of a ton per square inch.

Value for the internal pressure based on safety of tube.—By formula (5):

$$P_0=25.14373$$

and the dependent value for P_1 from equation (6) becomes

$$P_1=15.9982$$

Remarking the relative weakness of the trunnion hoop, we must, before adopting a final value for P_0, consider what will be the effect upon the trunnion hoop. We retain the first values for P_2 and P_3 which are calculated to develop the full elastic strength of both the hoop cylinders, and seek a suitable value for the pressure upon the interior of the trunnion hoop, system at rest, and therefrom determine what shrinkage that hoop will bear.

Pressures incident to the state of rest.—Retaining the values last deduced for P_0 and P_1 with the original values of P_2 and P_3, we find by formulas (9):

$p_1=-7.05065$ $p_2=-1.80187$ $p_3=-0.698172$ and by formulas (10):

$$P_1'=P_1+p_1=15.9982-7.05065=8.9475$$
$$P_2'=P_2+p_2=8.5632-1.80187=6.76133$$
$$P_3'=P_3+p_3=3.674-0.698172=2.9758$$

Whence, with the system at rest, the trunnion hoop may bear an interior pressure of 2.9758 tons per square inch. What in this case will be the value of φ_3? This is readily determined by computing the shrinkage for the state of rest, since P_3' is the single unknown quantity in the equations to be used.

From equation (20) we find:

$$\log. b' = (9.8899142)$$

and from equations (22) and (21):

$$\log. p_2' = (0.4527587)$$

and:

$$\varphi_3 = 0.00010736 + 0.0012095 = 0.0013169$$

This value is so near the corresponding one (0.0012972) deduced for the chamber section that we may adopt the latter, and thus favor also the trunnion hoop. Preserving, moreover, for simplicity of construction, the remaining shrinkages found for the chamber section, what will be the state of the system at rest and what interior pressure will this section support in the state of action?

The values for the shrinkages are as follows:

$$\varphi_1=0.00085594 \quad (6.9324433)$$
$$\varphi_2=0.001494 \quad (7.1743506)$$
$$\varphi_3=0.0012972 \quad (7.1130069)$$

The pressures in the state of rest induced by these shrinkages will be found as follows:

By substitution and reduction equation (21) becomes:

$$(a)\ \varphi_3=(7.1130069)=[(6.4701352)\ P_3'-(6.4343765)\ p_2']+(6.6090165)\ P_3$$

The value b' deduced from equation (20) and substituted in (22) gives, after reduction:

$$(b)\ \ldots\ldots\ldots\ p_2'=(9.9791550)\ P_3'$$

and by combining equations (*a*) and (*b*) we deduce:

$$P_3'= 2.8313.$$

with P_3' and φ_2 given by a similar reduction and combination of equations (19) and (20) we obtain:

$$P_2'= 6.45884$$

and with P_2' and φ_1 given, we find from equation (18):

$$P_1=8.2931$$

Final value for the internal pressure.—With P_1' known, the application of equation (8) gives the following value for the internal pressure, which will determine the elastic strength of the tube. We find:

$$P_0=24.55145$$

The remaining pressure for the system in action will now be found by applying equations (9) and (11); whence:

$$p_1=-cP_0=-6.85729 \quad p_2=-bp_1=-1.75244 \quad p_3=-ap_2=-0.633703$$

and

$$P_1=P_1'-p_1=8.2931\ +6.85729\ =15.15$$
$$P_2=P_2'-p_2=6.45884+1.75244\ =8.21$$
$$P_3=P_3'-p_3=2.9313\ +0.633703=3.565$$

The values present a uniform reduction from the first, which were obtained by the direct application of formulas (1).

Working tension of the trunnion hoop.—With $P_3=3.565$ this tension will be less than the value assumed, and by formula (27) we find:

$$\theta_3=15.525 \text{ tons per square inch.}$$

Tangential compression of the bore of tubes, system at rest.—With $P_1'=8.2931$, formula (24) gives:

$$\frac{\Delta R_0}{R_0}=-0.001483$$

The preceding adjustment of the shrinkages and pressures for this section gives a sufficient value for the internal resistance and obviates unnecessary strains for the state of rest.

SECTION IN FRONT OF POWDER CHAMBER.

$$\rho_0=\theta_0=22.143 \quad \rho_1=\theta_1=20 \quad \theta_2=24.28 \quad \theta_3=22.32$$
$$\varepsilon_0=0.0016 \quad \varepsilon_1=0.001445 \quad \varepsilon_2=0.0017 \quad \varepsilon_3=0.0015625$$
$$E_0=E_1=13{,}840 \quad E_2=E_3=14{,}286.$$
$$R_0=4.0 \quad R_1=7.0 \quad R_2=11.0 \quad R_3=13.15 \quad R_4=15.75$$

This section being between that of the powder chamber and trunnion hoop, we should, if practicable, use the same shrinkages as for those two sections. We may then examine the state of the system at rest and the pressures which it will support in action if assembled with the shrinkages.

$$\varphi_1=0.00085594 \qquad \varphi_2=0.001494 \qquad \varphi_3=0.0012972$$

Variations of pressure, system assembled.—It becomes necessary for an examination to first determine these values. The first two are the same as for the chamber section, and the third is found by applying the last equations (2), whence we obtain:

$$p_3=ap_2 \qquad \log.\ a=(9.6167878)$$
$$p_2=bp_1 \qquad \log.\ b=(9.4215663)$$
$$p_1=cp_0 \qquad \log.\ c=(9.4496326)$$

Pressures incident to the state of rest.—These values will be found as in the similar the case for trunnion hoop section. The value of b' derived from equation (20) and substituted in (22) gives an equation to combine with equation (21). The resulting equation contains the single unknown quantity P_3', and we obtain:

$$P_3'=3.26014$$

Then with P_3' and φ^3 given, the combination and reduction of equations (19) and (20) gives:

$$P_2'=6.77226$$

and with P_2 and φ_1 given, we find from equation (18):

$$P_1'=8.53816$$

Pressures incident to the state of action.—The remainder of the elementary cylinders will support all that the tube cylinder can bear, and for this latter, by applying equation (8), we find:

$$P_0=24.871$$

Equations (9) and (11) serve to determine the remaining values, viz:

$$p_1=-cP_0=-7.0037 \qquad p_2=-bp_1=-1.8488$$
$$p_3=-ap_2=-0.765035$$

and

$$
\begin{aligned}
P_1&=P_1'-p_1=8.53816+7.0037 &&=15.542\\
P_2&=P_2'-p_2=6.77226+1.8488 &&=8.621\\
P_3&=P_3'-p_3=3.26014+0.765035 &&=4.025
\end{aligned}
$$

The value for the internal resistance is suitable ;* it is a little greater than that deduced for the chamber section.

Working tension of the outer hoop.—We have $P_3=4.025$ tons, and by applying equation (27) find:

$$\theta_3=20.806$$

which is less than the corresponding tension (22.32 tons) for the outer hoop of the chamber section.

Tangential compression of the bore of tube, system at rest.—With $P_1'=8.53816$, formulas (24) gives:

$$\frac{\varDelta R_0}{R_0}=-0.0015268$$

Section near breech of tube.

$$\rho_0=\theta_0=22.143 \qquad \rho_1=\theta_1=20 \qquad \theta_2=24.28 \qquad \theta_3=22.32$$

$$\varepsilon_0=0.0016 \qquad \varepsilon_1=0.001445 \qquad \varepsilon_2=0.0017 \qquad \varepsilon_3=0.0015625$$

$$E_0=E_1=13,840 \qquad E_2=E_3=14,286$$

$$R_0=4.75 \qquad R_1=6.5 \qquad R_2=11.0 \qquad R_3=13.15 \qquad R_4=15.75$$

First values for the normal pressures, system in action.—The values P_3 and P_2 will be the same as for the chamber section, and for the others we apply formulas (1); whence:

$$P_3=4.31846 \qquad P_2=9.2492 \qquad P_1^{(2)}=18.2964 \qquad P_0^{(2)}=24.7674$$

Variations of pressure, system assembled.—By applying formulas (2) (log. a having the same value as for the chamber section) we find:

$$
\begin{aligned}
p_3&=ap_2 &\qquad \log. a&=(9.6167878)\\
p_2&=bp_1 &\qquad \log. b&=(9.3432590)\\
p_1&=cp_0 &\qquad \log. c&=(9.6892642)
\end{aligned}
$$

Trial value for initial compression of tube.—By formulas (3) and (4):

$$p_1=-c\,P_0=-12.11 \qquad P_1+p_1=18.2964-12.11=6.1864$$

$$(P_1+p_1)^1=6.19083$$

or there is a slight excess on the side of safety, so that we may use the first values for the normal pressures.

Pressures incident to the state of rest.—By formulas (9) and (10):

$$p_1=-c\,P_0=-12.11 \qquad p_2=-bp_1=-2.66934$$

$$p_3=-ap_2=-1.10457$$

and

$$
\begin{aligned}
P_1'&=P_1+p_1=18.2964-12.11 &&=6.1864\\
P_2'&=P_2+p_2=9.2492-2.66934 &&=6.57986\\
P_3'&=P_3+p_3=4.31846-1.10457 &&=3.21389
\end{aligned}
$$

Value of the first shrinkage.—With the given values of P_1' and P_2' we find by formula (18):

$$\varphi_1=0.00100283-0.00022232=0.00078051$$

---

*By the direct application of formulas (1) we would find $P_0^{(2)}=26.65$ tons per square inch.

Further examination would show the values of φ_2 and φ_3 to be on the other hand slightly *larger* than the corresponding values for the chamber section, but they may be used with propriety as they stand.

We have then to examine the condition of the section if assembled with the following shrinkages, viz:

$$\varphi_1=0.00078051 \qquad \varphi_2=0.001494 \qquad \varphi_3=0.0012972$$

Pressures incident to the state of rest.—Under these new conditions the values of P_3', P_2', and P_1' will be found as in the two preceding cases by applying formulas (22) to (18) inclusive, whence we obtain:

$$P_3'=3.2137 \qquad P_2'=6.57868 \qquad P_1'=6.18415$$

Pressures incident to the state of action.—Since the value P_1' is slightly reduced, that of P_0 will also be reduced from the first value; and since the values P_2' and P_3' are also smaller, we know that those of P_2 and P_3 will not reach the first values with P_0 acting; hence whatever pressure the tube can support will be safe for the system. By formula (8) we find:

$$P_0=24.764$$

and through formulas (9) and (11)

$$p_1=-c\ P_0=-12.1084 \qquad p_2=-bp_1=-2.66898$$
$$p_3=-ap_2=-1.10442$$

$$P_1=P_1'-p_1=6.18415+12.1084\ =18.293$$
$$P_2=P_2'-p_2=6.57868+\ 2.66898=\ 9.248$$
$$P_3=P_8'-p_3=3.2137\ +\ 1.10442=\ 4.318$$

or the values for the normal pressures in the state of action are practically the same as the first values.

Tangential compression of the bore of tube, system at rest.—With $P_1'=6.18415$, equation (24) gives:

$$\frac{\Delta R_0}{R_0}=-0.0015983$$

Action of the interior of jacket.—With the system in action the jacket cylinder may be subjected to the pressures $P_1=18.293$ and $P_2=9.248$, under which the tangential extension of its interior would be [last term of equation (12)]:

$$\frac{\Delta R_1}{R_1}=\frac{(4\ R_9^2+R_1^2)\ P_1-5\ R_2^2\ P_2}{3\ (R_2^2-R_1^2)\ E_1}=0.001233$$

With the system at rest the given shrinkages will produce a tangential compression of the interior, which we find by substituting the values of P_2' and P_2' for P_1 and P_2 in the equation above [or use the last term of equation (18)], whence:

$$\frac{\Delta R_1}{R_1}\underset{\Delta}{=}-0.000222$$

The above values show the range of the movement of interior of jacket from one extreme state of the system to the other.

Section around the breech-screw.

$$\rho_0=\theta_0=20 \qquad \theta_1=24.28 \qquad \theta_2=22.32$$
$$\varepsilon_0=0.001445 \qquad \varepsilon_1=0.0017 \qquad \varepsilon_2=0.0015625$$
$$E_0=13{,}840 \qquad E_1=E_2=14{,}286$$
$$R_0=5.5 \qquad R_1=11.0 \qquad R_2=13.15 \qquad R_3=15.75$$

The jacket constitutes the interior cylinder of this section; the powder pressure does not act within it, and the normal pressure produced by the rearward pressure of the breech-block on the inclined face of the thread will be relatively small in amount. The shrinkages will then turn principally upon the pressures incident to the state of rest and the tangential compression of the fibers at the interior of jacket or bottom of threads and sectors.

In this case we have a system composed of but three elementary cylinders, and in place of formulas (1) we use the following to find the values of the normal pressures calculated to determine the elastic limits of the elementary cylinders of the combined system for the state of action, viz:

$$(28)\ \ldots\ \left\{\begin{array}{ll}
P_2 = \dfrac{3\,(R_3^2 - R_2^2)\ \theta_2}{4\,R_3^2 + R_2} & \Big\}\text{ for the third cylinder.} \\[2ex]
\left.\begin{array}{l} P_1^{(1)} = \dfrac{3\,(R_2^2 - R_1^2)\ \theta_1 + 5\,R_2^2\,P_2}{4\,R_2^2 + R_1^2} \\[2ex] P_1^{2} = \dfrac{3\,(R_2^2 - R_1^2)\ \rho_1 + 3\,R_2^2\,P_2}{4\,R_2^2 - R_1^2} \end{array}\right\} & \text{for the second cylinder.} \\[4ex]
\left.\begin{array}{l} P_0^{(1)} = \dfrac{3\,(R_1^2 - R_0^2\ \theta_1 + 5\,R_1^2\,P_1}{4\,R_1^2 + R_0^2} \\[2ex] P_0^{2} = \dfrac{3\,(R_1^2 - R_0^2)\ \rho^0 + 3\,R_1^2\,P_1}{4\,R_1^2 - R_0^2} \end{array}\right\} & \text{for the first cylinder.}
\end{array}\right.$$

And for the variations of pressure in the assembled system in place of formulas (2) we have the following:

$$(29)\quad \begin{array}{l}
p_2 = \dfrac{5\,R_1^2\,E_2\,(R_3^2 - R_2^2)}{E_2\,(R_3^2 - R_2^2)\,(4\,R_1^2 + R_2^2) + E_1\,(R_2^2 - R_1^2)\,(4\,R_3^2 + R_2^2)}\,p_1 = bp_1 \\[3ex]
p_1 = \dfrac{5\,R_0^2\,E_1\,(R_2^2 - R_1^2)}{E_1\,(R_2^2 - R_1^2)\,4\,R_0^2 + R_1^2) + E_0\,(R_1^2 - R_0^2)\,[(4\,R_2^2 + R_1^2) - 5\,R_2^2\,b]}\,p_0 = cp_0
\end{array}$$

First values for the normal pressures, system in action.—The pressures which the system under the full portion of the double hooping would support in action, derived from formulas (28), are as follows:

$P_2 = 4.31846$ $\qquad P_1 = 9.2492$ $\qquad P_0^{(2)} = 19.3993$

in which P_2 and P_1 are the same as P_3 and P_2 for the chamber section.

Variations of pressure, system assembled.—By applying formulas (29) we find:

$p_2 = bp_1$ $\qquad \log.\ b = (9.6167878)$

$p_1 = cp_0$ $\qquad \log.\ c = (9.1744059)$

in which the coefficient *b* has the same value as *a* for the chamber section.

Trial value for initial compression of jacket.—By formulas (3) and (4):

$$p_1 = -c\ P_0 = -2.8986$$
$$P_1' = P_1 + p_1 = 9.2492 - 2.8986 = 6.3506$$
$$(P_1 + p_1)^{(1)} = 9.000$$

or the excess on the side of safety is about 2.65 tons per square inch, and we may use the values already found for P_2, P_1, and P_0.

Pressures incident to the state of rest.—We have $P_1'=6.3506$, and from formulas (9) and (10):

$$p_2=-bp_1=-1.1995 \qquad P_2'=P_2+p_2=4.31846-1.1995=3.11902$$

The shrinkages computed for the state of rest.—Applying formulas (18), (19), and (20) whilst placing $P_3'=0$, we find

$$\varphi_1=0.0004079+0.0011074=0.0015153$$
$$\varphi_2=0.00015353+0.00112853=0.00128206$$

These values differ but little from the corresponding ones (φ_1 and φ_2) for the chamber section, so the latter may be substituted for them. We have then to discuss the state of rest for the shrinkage values.

$$\varphi_1=0.001494 \qquad \varphi_2=0.0012972$$

Pressures incident to the state of rest.—Placing $P_3'=0$ in equation (19), reducing and combining with equation (20), we find

$$P_2'=3.155835$$

Then, with P_2' and φ_1 given, the solution of equation (18) gives

$$P_1'=6.33424$$

Tangential compression of interior of jacket, system at rest.—With P_1' given, we find from formula (24)

$$\frac{\Delta R_0}{R_0}=-0.0010171$$

This would be the maximum compression at the interior of the breech recess under the full double hooping if we used the shrinkages last named. In the adjacent section (through breech of tube) it was found that with the full elastic resistance ($P_0=24.764$) developed, the tangential *extension* of the fibers at the interior of jacket would be 0.001233. Hence, if we should use the shrinkages the *total effect* at angle in jacket near breech of tube might reach the sum:

$$0.001233\times0.001017=0.00225$$

which considerably exceeds the elastic extension of the jacket metal; and it would seem best to lighten the shrinkage of hoop B_{10} in order to reduce the tangential compression at the interior of jacket in the recess next base of tube.

Assume that the tangential compression at interior of jacket as above shall be limited to the value:

$$\frac{\Delta R_0}{R_0}=-0.00075$$

Retain the shrinkage $\varphi_1=0.001494$ for the two inner hoops; then what should be the shrinkage for hoop B_{10}? We have, equation (24):

$$\frac{\Delta R_0}{R_0}=-0.00075=\frac{5R_1^2P_1'}{3(R_1^2-R_0^2)E_0}$$

whence:

$$P_1'=4.67076$$

and with P_1' and φ_1 given, we find, through formula (18):

$$P_2'=1.3173$$

With the values P_1' and P_2' given, and $P_3'=0$, the required shrinkage for hoop B_{10} is found through equations (19) and (20):

$$\varphi_2=0.00006484+0.00047662=0.0005415$$

The shrinkage values for the double hooping over the breech recess are then:

$$\varphi_1=0.001494 \qquad \varphi^2=0.0005415$$

involving a tangential compression at the interior of jacket, as above, equal to 0.00075. The total effect at the angle in jacket may then reach the sum:

$$0.001233+0.00075=0.001983$$

which, although still in excess of the safe limit for the jacket metal under extension, may not be considered unsafe, and, moreover, will be reduced by whatever tangential extension of the interior fibers of the jacket is occasioned in this intermediate recess by the powder pressure forward and the normal pressure transmitted by the block to the screw-thread and tending to extend the interior of the jacket at its rear. The adjusted shrinkage for hoop B_{10} is slight, but this shrinkage may be made heavier toward the rear, where the hoop is thinned, and the hoop will be firmly retained in place during the service of the gun. The shrinkage for the rear portion of hoop B_9 will be lightened to approach the value $\varphi_2=0.0005415$.

Effect produced by the single hoop A_{12}.—This hoop is to be assembled with the uniform shrinkage used for the remainder of the row. The tangential compression produced at the interior of the jacket under the full portion of the hoop is found through equations (18) and (24). We have $\varphi_1=0.001494$; hence:

$$P_1'=3.47893 \qquad \frac{\varDelta R_0}{R_0}=-0.00055862$$

which compares favorably with the compression in the forward portion of the recess.

This completes the discussion of the tangential strains in the reinforce of the gun, and we pass next to the portion forward of the trunnion hoop.

Section through base of hoop A_1.

$$\rho_0=\theta_0=22.143 \qquad \rho_1=\theta_1=20 \qquad \theta_2=23.0$$
$$\varepsilon_0=0.0016 \qquad \varepsilon_1=0.001445 \qquad \varepsilon_2=0.00161$$
$$E_0=E_1=13{,}840 \qquad E_2=14{,}286$$
$$R_0=4.0 \qquad R_1=7.0 \qquad R_2=11.0 \qquad R_3=15.0$$

First values for the normal pressures, system in action.—By applying formulas (28) we find:

$$P_2=6.40142 \qquad P_{1(2)}=15.2729 \qquad P_0^{(2)}=24.6514$$

Variations of pressure, system assembled.—By formulas (29):

$$p_2=bp_1 \qquad \log.b=(9.3602597)$$
$$p_1=cp_0 \qquad \log.c=(9.4351419)$$

Trial value for initial compression of tube.—By formulas (3) and (4):

$$p_1=-cP_0=-6.71403$$
$$P_1'=P_1+p_1=15.2729-6.71403=8.55887$$

and:

$$(P_1+p_1)^{(1)}=8.9475$$

Whence the safety excess is equal to 0.3886 tons per square inch, and we may use the values already determined.

Pressures incident to the state of rest.—We have $P_1'=8.55887$, and from formulas (9) and (10):

$$p_2=-bp_1=-1.539 \qquad P_2'=P^2+p^2=6.40142-1.539=4.86227$$

The shrinkages, computed for the state of rest.—Placing $P_3'=0$, and applying formulas (18) to (20) inclusive, we find:

$$\varphi_1=0.0007059+0.000542=0.0012479$$
$$\varphi_2=0.00026632+0.0012229=0.0014\ 92$$

Tangential compression of bore of tube, system at rest.—With the shrinkages given above and $P_1'=8.55887$, we find, by formula (24):

$$\frac{\varDelta R_0}{R_0}=-0.0015305$$

The pressure on exterior of tube and compression of bore, system at rest, would thus exceed the corresponding values 8.293 and 0.001449 for the adjacent trunnion hoop section. The first shrinkage is also greater than for that section, and it is not desirable to have it so. Let us then assume, in order to retain a uniform shrinkage along the jacket:

The first shrinkage:

$$\varphi_1=0.00085594$$

and the tangential compression of bore:

$$\frac{\varDelta R_0}{R_0}=-0.00125$$

What, then, will be the pressures incident to the state of rest, the value of the second shrinkage, the elastic resistance of the section to an interior pressure and the working limit of the outer hoop with the system in action?

Pressures incident to the state of rest.—With

$$\frac{\varDelta R_0}{R_0}=-0.00125$$

formula (23) gives

$$P_1'=6.990285$$

and with P_1' and φ_1 given we find from formula (18):

$$P_2'=4.7778$$

The second shrinkage.—Placing $P_3'=0$, and applying formulas (19) and (20), we find:

$$\varphi_2=0.00020275+0.00120165=0.0014044$$

Elastic resistance to interior pressures—pressures for the state of action.—With P_1' given, we obtain P_0 through formula (8) and the remaining pressures for this state through formulas (9) and (11), whence

$$P_0=23.004 \qquad p_1=-c\,P_0=-6.26535 \qquad p_2=-bp_1=-1.43617$$

$$P_1=P_1{}^1-p_1=6.990285+6.26535=13.2556$$

$$P_2=P_2'-p_2=4.7778+1.43617=6.21397$$

Working tension of the outer hoop for the state of action.—By formula (27)

$$\theta_2=22.326$$

for which the corresponding tangential extension of interior fiber equals 0.0015628.

Section through shoulder of jacket (within front edge).

$\rho_0=\theta_0=22.143$ $\rho_1=\theta_1=20$ $\theta_2=23$

$\varepsilon_0=0.0016$ $\varepsilon_1=0.001445$ $\varepsilon_2=0.00161$

$E_0=E_1-13{,}840$ $E_2=14{,}286$

$R_0=4.0$ $R_1=7.0$ $R_2=11.6$ $R_3=14.64$ (approximate).

A preliminary examination shows that it will be proper to assemble this section with the same shrinkages as the adjacent one to the rear (through base of hoop A_1). We have then to discuss the action of the system.

It will not be permissible to exceed the allowable pressure for the outer hoop, which through the first of formulas (28) we find to be

$$P_2=5.54917$$

Variations of pressure, system assembled.—By formulas (29)

$$p_2=bp_1 \qquad \log.\ b=(9.2552467)$$

$$p_1=cp_0 \qquad \log.\ c=(9.4365357)$$

Pressures incident to the state of rest.—The given shrinkage values are

$$\varphi_1=0.00085594 \qquad \varphi_2=0.0014044$$

Commencing with the latter and combining formulas (19) and (20), placing $P_3'=0$, we find after reduction

$$P_2'=4.24969$$

Then, with P_2' and φ_1 given, we obtain, through formula (18)

$$P_1'=6.70257$$

Pressures incident to the state of action.—As in the preceding section, by applying formulas (8), (9), and (11), we find:

$$P_0=22.723 \qquad p_1=-c\,P_0=-6.20863 \qquad p_2=-bp^1=-1.1175$$

$$P_1=P_1'-p_1=6.70257+6.20863=12.9102$$

$$P_2=P_2'-p_2=4.24969+1.1175=5.3672$$

Tangential compression of bore of tube, system at rest.—By formula (24):

$$\frac{\Delta R_0}{R_0}=-0.0011985$$

Working tension of the outer hoop for the state of action.—By formula (27):

$$\theta_2=22.245$$

for which the corresponding tangential extension of interior fiber equals 0.0015572.

Section through front (within face) of jacket.

$\rho_0=\theta_0=22.143$ $\rho_1=\theta_1=20$ $\theta_2=21.8$

$\varepsilon_0=0.0016$ $\varepsilon_1=0.001445$ $\varepsilon_2=0.001526$

$E_0=E_1=13{,}840$ $E_2=14{,}286$

$R_0=4$ $R_1=7.25$ $R_2=9.9$ $R_3=12.65$

First values for the normal pressures, system in action.—By formulas (28):

$$P_2=5.49467 \qquad P_1^{(1)}=12.18956 \qquad P_0^{(2)}=22.3986$$

Variations of pressure, system assembled.—By formulas (29):

$$p_2=bp_1 \qquad \log.\ b=(9.4993706)$$

$$p_1=cp_0 \qquad \log.\ c=(9.3593267)$$

Pressures incident to the state of rest.—By formulas (9) and (10):

$$p_1=-c\,P_0=-5.12329 \qquad p_2=-bp_1=-1.61774$$

and

$$P_1'=P_1+p_1=12.18956-5.12329=7.06627$$

$$P_2'=P_2+p_2=5.49467-1.61774=3.87693$$

The shrinkages computed for the state of rest.—By formulas (18), (19), and (20), with $P_3'=0$.

$$_1=0.0005426+0.0006581=0.0012007$$

$$\varphi_2=0.0001845+0.0010767=0.0012612$$

These values are not suitable. The jacket, where it is threaded, will not perform the calculated work, and the shrinkage of the D hoop should be relatively increased. It is desirable, moreover, to retain a uniform value for the shrinkage of the jacket; we may then assume φ_1 to be the same as for the preceding sections and deduce a new value for φ_2. This will decrease the theoretical resistance of the section, because the tension within the D hoop "at rest" will be increased.

The most direct method for making the adjustment required will be to assume a minimum (allowable) value for P_0, find the pressure *transmitted* to the D hoop for the state of action, and thus deduce the pressure allowable for it in the state of rest. The construction will be safe if we take $P_0=18$ tons; the powder pressure in this section will not reach this figure, and moreover, even in that event, the D hoop would be strained only to the relatively low value, $\theta_2=21.8$ tons.

The assumed conditions then are:

$$P_0=18.0 \qquad \varphi_1=0.00085594$$

Pressure transmitted to interior of D hoop system in action.—By combining the first two of equations (9) we obtain:

$$p_2=-cb\,P_0$$

whence with $P_0=18$,

$$p_2=-1.30008$$

Pressures incident to the state of rest.—We have already found that P_2 may equal 5.49467 tons; then, formulas (10),

$$P_2'=P_2+p_2=5.49467-1.30008=4.1946.$$

and by formula (18) with P_2' and φ_1 given, we obtain:

$$P_1'=6.22678$$

The second shrinkage.—By formulas (19) and (20), with $P_3'=0$, we have:

$$\varphi_2=0.0001996+0.0011649=0.0013645$$

Tangential compression of bore of tube, system at rest.—By formula (24):

$$\frac{\Delta R_0}{R_0}=-0.001078$$

We have assumed a comparatively low value for P_0 as above, especially with reference to an adjustment of the shrinkages. This value for P_0 will develop a tension in the outer hoop equal to 21.8 tons, but will not develop the elastic strength of the tube. Having $P_1'=6.22678$ tons, the elastic strength of the tube would be developed only in case P_0 reached the value to be found by applying formula (8); whence:

$$P_0=21.563 \text{ tons.}$$

The shrinkages remaining the same, we find by formulas (9) and (11) that the remaining pressure in the state of action would then be as follows:

$$p_1=-c\,P_0=-4.93215 \qquad p_2=-bp_1=-1.55742$$

then

$$P_1=P_1'-p_1=6.22678+4.93215=11.15893$$

$$P_2=P_2'-p_2=4.1946\ +1.55742=\ 5.75202$$

But if P_2 equals the above value, the tangential tension in the D hoop for the state of action as found through formula (27) becomes:

$$\theta_2=22.82 \text{ tons,}$$

or about 1 ton per square inch greater then the value at first assumed. However, the tension 22.82 tons cannot be considered excessive for the metal of this hoop, and we may adopt the value $P_0=21.563$ tons to represent the tangential resistance of this section of the gun.

Section through middle of D row of hoops (outside).

$$\rho_0=\theta_0=22.143 \qquad \rho_1=\theta_1=23.5 \qquad \theta_2=21.8$$

$$\varepsilon_0=0.0016 \qquad \varepsilon_1=0.001645 \qquad \varepsilon_2=0.001526$$

$$E_0=13,840 \qquad E_1=E_2=14,286$$

$$R_0=4 \qquad R_1=7.875 \qquad R_2=9.9 \qquad R_3=12.325$$

First values for the normal pressures, system in action.—By formulas (28):

$$P_2=4.9952 \qquad P_1^{(1)}=10.98 \qquad P_0^{(2)}=21.9748$$

Variations of pressure, system assembled.—By formulas (29):

$$p_2=bp_1 \qquad \log.\ b=(9.5790730)$$

$$p_1=cp_0 \qquad \log.\ c=(9.2421317)$$

Pressures incident to the state of rest.—By formulas (9) and (10):

$$p_1=-c\,P_0=-3.8376 \qquad p_2=-bp_1=-1.4559$$

and

$$P_1'=P_1+p_1=10.98\quad -3.8376=7.1424$$

$$P_2'=P_2+p_2=\ 4.9952-1.4559=3.5393$$

The shrinkages, computed for the state of rest.—By formulas (18), (19), and (20), with $P_3'=0$:

$$\varphi_1=0.0004711+0.000978=0.0014491$$

$$\varphi_2=0.0001668+0.0010812=0.001248$$

Tangential compression of bore of tube, system at rest.—By formula (24):

$$\frac{\Delta R_0}{R_0}=-0.0011592$$

These results are unsatisfactory in several respects. The first shrinkage is unnecessarily heavy; the pressure on tube in the state of rest and also the compression of the bore is greater than for the adjacent section to the rear. A preliminary examination shows that a shrinkage value, $\varphi_1=0.001$, is well adapted to the assemblage of the whole *C* row of hoops (single and double hooping). To deduce the value for the second shrinkage in this section (double hooping) we will assume that the *D* row of hoops shall be subjected to a tangential tension of 20.5 tons when the pressure in bore of gun amounts to 17.75 tons per square inch.

The conditions are then as follows:

$$\varphi_1=0.001 \qquad \theta_2=20.5 \qquad P_0=17.75$$

Limiting pressure for D hoop, system in action.—If $\theta_2=20.5$, we find, formulas (28):

$$P_2=4.69732$$

Pressures incident to the stateof rest.—We have $P_0=17.75$, and find P_2 as in the preceding section, viz:

$$p_2=-cb\ P_0=-1.176$$

then

$$P_2'=P_2-p_2=4.69732-1.176=3.5213$$

The value of P_1' is obtained, with P_2' and φ_1 given, by formula (18) whence

$$P_1'=5.8552$$

The second shrinkage.—By formulas (19) and (20):

$$\varphi_2=0.0001659+0.0010757=0.0012416.$$

Tangential compression of bore of tube, system at rest.—By formula (24)

$$\frac{\Delta R_0}{R_0}=0.00095032$$

Having obtained suitable values for the shrinkages, it may readily be shown that whilst retaining these values for the assemblage the system will safely support a greater interior pressure than 17.75 tons, which gives the low value $\theta_2=20.5$ for the tangential tension of the outer hoop.

With the pressure $P_1'=5.8552$ tons upon the exterior of tube, system at rest, that cylinder would safely support, formula (8), the following interior pressure:

$$P_0=20.775$$

and the remaining pressures in the state of action, formulas (9) and (11), would then be as follows:

$$p_1=-c\,P_0=-3.628075 \qquad p_2=-bp_1=-1.37641$$

then

$$P_1=P_1'-p_1=5.8552+3.628075=9.483$$

$$P_2=P_2'-p_2=3.5213+1.37641=4.8977$$

with this value for P_2 we find, formula (27):

$$\theta_2=21.374$$

which represents the tangential tension at interior of D hoop for $P_0 = 20.775$; hence it is seen that the system can safely support the interior pressure just named. It is not necessary to examine into the behavior of the middle cylinder, because the pressures $P_1 = 9.483$ and $P_2 = 4.8971$ are seen to be safe when compared with the first values deduced for the normal pressures, system in action.

Section through base of C row of hoops (single hooping.)

$\rho_0 = \theta_0 = 22.143$ $\theta_1 = 23.0$ $\varepsilon_0 = 0.00160$ $\varepsilon_1 = 0.00161$

$E_0 = 13{,}840$ $E_1 = 14{,}286$ $R_0 = 4.0$ $R_1 = 7.875$ $R_2 = 10.375$

In this and the succeeding section we have a system composed of but two elementary cylinders.

The maximum values for the normal pressures which the elementary cylinders will support in combination are derived from the following:

$$(30) \quad \cdots\cdots \quad \begin{cases} P_1 = \dfrac{3\,(R_2^2 - R_1^2)\,\theta_1}{4\,R_2^2 + R_1^2} & \text{for the second cylinder.} \\ P_0^{(1)} = \dfrac{3\,(R_1^2 - R_0^2)\,\theta_0 + 5\,R_1^2\,P_1}{4\,R_1^2 + R_0^2} & \multirow{2}{*}{for the first cylinder.} \\ P_0^{(2)} = \dfrac{3\,(R_1^2 - R_0)\,\rho_0 + 3\,R_1^2\,P_1}{4\,R_1^2 - R_0^2} & \end{cases}$$

And from the general equations of equilibrium for the system, to express the variations of pressure in the assembled system for changes of state, we have:

$$31) \quad . \; . \quad p_1 = \frac{5\,R_0^2\,(R_2^2 - R_1^2)\,E_1}{E_0\,(R_1^2 - R_0^2)\,(4\,R_2^2 + R_1^2) + E_1\,(R_2^2 - R_1^2)\,(4\,R_0^2 + R_1^2} = cp_0$$

First values for the normal pressures, system in action.—By formulas (30):

$$P_1 = 6.39112$$
$$P_0^{(2)} = 18.2959$$

Variations of pressure, system assembled.—By formula (31):

$$p_1 = cp_0 \qquad \log.\ c = (9.1196966)$$

Pressure incident to the state of rest.—By formulas (9) and (10):

$$p_1 = -c\,P_0 = -2.4102 \qquad P_1' = P_1 + p_1 = 6.39112 - 2.4102 = 3.9809$$

The shrinkage computed for the state of rest.—We have $P_2' = 0$; and by formula (18):

$$\varphi_1 = 0.0002626 + 0.0010028 + 0.0012654$$

Tangential compression of bore of tube, system at rest.—By formula (24):

$$\frac{\varDelta R_0}{R_0} = -0.0006462$$

These values for the shrinkage and compression of the bore are not excessive, but wishing to use a single shrinkage value for the whole of the C row of hoops and considering the adjustment of the system, especially the compression of bore, at the muzzle end of this row (see following), we take the value already named as suitable for the whole, viz:

$$\varphi_1 = 0.001$$

The condition of the system then becomes as follows:

Pressure incident to the state of rest.—By formula (18), with $P_2'=0$, and φ_1 given, we find,

$$P_1'=3.1464$$

Tangential compression of bore of tube, system at rest.—By formula (24):

$$\frac{\varDelta R_0}{R_0}=-0.000510672$$

Pressures incident to the state of action.—The interior resistance is limited by the elastic strength of the tube cylinder, which with $P_1'=3.1464$ becomes, formula (8):

$$P_0=17.548$$

and for the remaining pressure value we find

$$p_1=-c\,P_0=-2.31164$$

then

$$P_1=P_1'-p_1=3.1464+2.31164=5.458$$

Tangential tension of the hoop, system in action.—Substituting the above value for P_1 with the necessary changes of notation in formula (27), we find:

$$\theta_1=19.642$$

which leaves the hoop with a considerable reserve of elastic strength.

Section through hoop C_8, at base of incline.

$\rho_0={}_0=22.143$ $\theta_1=23.0$ $\varepsilon_0=0.0016$ $\varepsilon_1=0.00161$

$E_0=13{,}840$ $E_1=14{,}286$ $R_0=4.0$ $R_1=7.875$ $R_2=9.79$

First values for the normal pressures, system in action.—By formulas (30):

$$P_1=5.2407 \qquad P_0^{(2)}=17.3736$$

Variations of pressure, system assembled.—By formula (31):

$$p_1=cp_0 \qquad \log. c=(9.0500415)$$

Pressure incident to the state of rest.—By formulas (9) and (10):

$$p_1=-c\,P_0=-1.94954$$

$$P_1'=P_1+p_1=5.2407-1.94954=3.29116$$

The shrinkage computed for the state of rest.—We have $P_2'=0$; and by formula (18):

$$\varphi_1=0.0002171+0.001011=0.0012281$$

Tangential compression of bore of tube, system at rest.—By formula (24):

$$\frac{\varDelta R_0}{R_0}=-0.00053417$$

Since the compression of the bore ends with the hooping, it is thought best to slightly reduce the above shrinkage value and compression of bore, and to arrange the shrinkage with a view to make the *steps* of the compression about equal at this place and at the end of the double hooping to the rear. The value $\varphi_1=0.001$ fulfills the requirements of the case and enables a uniform value to be used for the whole C row of hoops as before stated. It reduces the amount of unnecessary strain in this part of the gun for the system at rest and provides an ample value for P_0.

We then take $\varphi_1=0.001$ and find the condition of the system as follows:

Pressure incident to the state of rest.—We have φ_1 given and $P_2' = 0$; then formula (18):

$$P_1'=2.6797$$

Tangential compression of bore of tube, system at rest.—By formula (24):

$$\frac{\Delta R_0}{R_0} = -\ 0.00043493.$$

Pressures incident to the state of action.—The interior resistance becomes, formula (8):

$$P_0=16.835$$

and for the remaining pressure value

$$p_1= -c\ P_0=-\ 1.8891$$

then

$$P_1=P_1'-p_1=2.6797+1.8891=4.5688$$

Tangential tension of the hoop, system in action.—By formula (27):

$$\theta_1=20.051$$

Using the shrinkage $\varphi_1=0.001$, the pressure in the state of rest as shown above is $P_1'=2.6797$, which, formula (27), will make the tangential tension in the hoop at *rest* as follows:

$\theta_1=11.76$ tons or 26,343 pounds per square inch, which may be regarded as amply sufficient to prevent any loosening of these hoops in the service of the gun.

Unhooped portion of the tube.

The elastic resistance of any section of the hollow cone which forms the muzzle end of the gun is derived from the following formula:

$$(32) \quad . \ . \ . \ . \ . \ . \ . \quad P_0=\frac{3\ (R_1^2-R_0^2)\ \theta_0}{4\ R_1^2+R_0^2}$$

At the base of this cone, adjoining the hoops, we have: $\theta_0=22.143$, $R_0=4$, and $R_1=7.875$. Then, formula (32):

$$P_0=11.576.$$

At the muzzle we have $\theta_0=22.143$, $R_0=4$, and $R_1=6.5$; hence,

$$P_3=9.426$$

The following table contains a summary of the values adopted from the results of the tests of detached specimens to represent the physical properties of the metals within the elastic limits, and also the results of the preceding computations which relate generally to the action of the tangential and radial forces of the system, or those which act in planes perpendicular to the axis of the gun:

Summary table of values and results of computations.

[Physical properties of the metals. Limiting values assumed.]

Notations.	Tube.	Jacket.	A hoops excepting A_1.	Hoop A_1.	B hoops, excepting trunnion hoop.	Trunnion hoop.	C hoops.		D hoops.
							Double hooping.	Single hooping.	
ρ tons per square inch	22.143	20.0	24.28	23.0	22.32	16.0	23.5	23.0	21.8
θ tons per square inch	22.143	20.0	24.28	23.0	22.32	16.0	23.5	23.0	21.8
e inches	0.0016	0.001445	0.0017	0.00161	0.0015625	0.001493	0.001645	0.00161	[illegible]
E tons per square inch	13.840	13, 840	14, 286	14, 286	14, 286	10, 714	14, 286	14, 286	14, 286

Sections of the gun.	Diameters.					Shrinkages.					
						First.		Second.		Third.	
	D_0.	D_1.	D_2.	D_3.	D_4.	Relative (in thousandths).	Absolute.	Relative (in thousandths).	Absolute.	Relative (in thousandths).	Absolute.
	In.	*In.*	*In.*	*In.*	*In.*		*Inch.*		*Inch.*		*Inch.*
Breech:											
Single hooping	11.0	22.0	26.3	......	......	1.494	0.0329	....	....	....	....
Double hooping	11.0	22.0	26.3	31.5	......	1.494	0.0329	0.5415	0.0142	....	....
Breech of tube	9.5	13.0	22.0	26.3	31.5	0.78051	0.010	1.494	0.0329	1.2972	0.0341
Powder-chamber	9.5	14.0	22.0	26.3	31.5	0.85594	0.012	1.494	0.0329	1.2972	0.0341
Between chamber and trunnion hoop	8.0	14.0	22.0	26.3	31.5	0.85594	0.012	1.494	0.0329	1.2972	0.0341
Trunnion hoop	8.0	14.0	22.0	26.3	32.76	0.85594	0.012	1.494	0.0329	1.2972	0.0341
Base of hoop A_1	8.0	14.0	22.0	30.0	......	0.85594	0.012	1.4044	0.031	....	....
Shoulder of jacket (within front edge)	8.0	14.0	23.2	29.28	......	0.85594	0.012	1.4044	0.0326	....	....
Forward end of jacket (within face)	8.0	14.5	19.8	25.3	......	0.85594	0.0122	1.3645	0.027	....	....
Middle of D row of hoops (outside)	8.0	15.75	19.8	24.65	......	1.000	0.0160	1.2416	0.0246	....	....
Base of C row of hoops (single hooping)	8.0	15.75	10.75	......	......	1.000	0.0160	....	....	....	....
End hoop of C row of hoops (foot of incline)	8.0	15.75	19.58	......	......	1.000	0.0157	....	....	....	....
Unhooped portion of gun:											
Base	8.0	15.75	......	......	......	....	....	....	....	....	....
Muzzle	8.0	13.0	......	......	......	....	....	....	....	....	....

Summary table of values and results of computations—Continued.

Sections of the gun.	System at rest.					System in action.					
	Normal pressure per square inch.			Relative tangential compression.		Normal pressures per square inch.				Working limits of interior fibers of outer hoop.	
	P_1'	$'P_2'$	P_2'	Interior of jacket (in thousandths).	Bore of tube (in thousandths).	P_0	P_1	P_2	P_3	Tangential tension (in tons per square inch).	Tangential extensions.
reech:	*Tons.*	*Tons.*	*Tons.*			*Tons.*	*Tons.*	*Tons.*	*Tons.*		*Inch.*
Single hooping	3.48	......	......	0.5586	.....	......	......	......	......	......	....
Double hooping	4.67	1.32	......	0.750	.....	......	......	......	......	......	....
reech of tube	6.184	6.579	3.214	0.222	1.60	24.76	18.29	9.25	4.32	22.32	0.0015625
owder-chamber	7.168	6.579	3.214	......	1.60	24.774	17.283	9.25	4.32	22.32	0.0015625
etween chamber and trunnion hoop	8.54	6.77	3.26	......	1.527	24.87	15.54	8.62	4.03	20.81	0.0014564
runnion hoop	8.29	6.46	2.93	......	1.483	24.55	15.15	8.21	3.56	15.525	0.001449
ase of hoop A_1	6.99	4.78	......	......	1.250	23.00	13.26	6.21	......	22.33	0.001563
houlder of jacket (within front edge)	6.70	4.25	......	......	1.200	22.72	12.91	5.37	......	22.25	0.0015572
orward end of jacket (within face	6.23	4.20	......	......	1.078	21.563	10.34	5.49	......	22.82*	0.0015974
iddle of D row of hoops (outside)	5.86	3.52	......	......	0.95	20.775	8.95	4.70	......	21.374	0.001496
ase of C row of hoops (single hooping)	3.15	......	......	......	0.51	17.55	5.46	......	......	19.64	0.001435
nd hoop of C row of hoops (foot of incline)	2.68	......	......	......	0.435	16.83	4.57	......	......	20.05	0.001436
nhooped portion of gun:											
Base	......	......	......	......	.....	11.58	......	......	......	......	....
Muzzle	......	......	......	......	.....	9.43	......	......	......	......	....

* This exceeds the value, $\theta_2 = 21.8$ adopted, but it is still about 10 per cent. below the elastic limit de-ermined for the metal of these (D) hoops by the tests of detached specimens.

In the plate is shown to given scales the curves of velocity and pow-er pressure for a powder charge of 100 pounds and projectile weighing 85 pounds, the "density of loading" being taken at 0.9; these compu-ations were made in the office of the Chief of Ordnance, U. S. Army. he plate shows also the curves of relative compression of bore of tube nd breech-recess in jacket for the state of rest, and the computed elas-ic resistance of the gun. The computed shrinkages for the gun are ritten in their appropriate places and are expressed in relative and bsolute values.

LONGITUDINAL RESISTANCE OF THE GUN.

The jacket cylinder is called upon to support the longitudinal thrust eveloped by the pressure in the powder-chamber when the gun is fired. his pressure, acting upon the bottom of the bore, is transmitted through he head of the block and the block itself; first to the bearing surface f the thread in the screw recess, where, since the pressure acts upon he surface of the thread alone, the effect is such that the strain upon he jacket is locally confined, at least in a great measure, to the fibers t the interior of the jacket or the bottom of the threads of its screw; nd second, to the whole cross-section of the jacket in a measure which ill approach a uniformity of strain in the whole sectional area on leav-ng the zone of intense local (interior) strain at or near the base of the hread as above indicated. In this gun we have to consider two planes of weakness, or rather two places at which the longitudinal resistance of the cylinder will be most severely tested. The first follows the base of the thread in the jacket for one complete turn at the forward portion of the thread. The second is in the zone lying between a plane perpendicular to the axis of the piece through the base of the spindle head of the block and a similar plane through the rear face of the tube. This zone may be considered sufficiently removed from the locality of the thread to warrant the assumption that within its limits the longitudinal strain thus far considered shall be uniformly distributed throughout the cross-sectional area of the jacket.

We will consider the longitudinal resistance in relation to the safe tangential resistance of the gun as already determined, that is, instead of seeking the extreme elastic longitudinal resistance we must determine the amount of longitudinal strain under the supposition that the interior pressure in the powder-chamber is given by the value $P_0=24.764$ tons per square inch previously deduced for the "section near breech of tube." The amount of strain so determined may then be compared with the elastic properties of the metal determined by the free tests to ascertain if the longitudinal resistance is within safe limits.

Assuming that the pressure in the powder-chamber may reach the value $P_0=24.764$ tons per square inch, the total pressure upon the bottom of the bore or chamber, which has a radius of 4.75 inches, will be:

$$\pi R_0^2 P^0 = 1755.3 \text{ tons}$$

which represents the maximum rear thrust acting parallel to the axis of the piece that would be transmitted through the block to the bearing surface of the thread in the screw recess of the jacket. This presupposes that the gun has no recoil, and moreover neglects the force expended in compressing the gas check pad and the friction of the gas check against the wall of the tube.*

The cross-section of jacket near breech of tube.

It is assumed for this cross-section that the longitudinal strain is uniformly distributed throughout the area. We arrive at a value for the strain by considering the displacement of the fibers in the direction of the length. Such displacement is produced not only by the pressure on the bottom of the bore when the gun is fired, but also by the normal pressures which then act upon the jacket cylinder and tend to change its length. The following formula expresses the longitudinal resistance per square inch in the cross-section of the jacket under consideration, due to the powder pressure in the bore combined with the interior and exterior normal pressures acting upon the jacket cylinder, viz:

$$(34)\dagger \quad . \quad . \quad . \quad . \quad . \quad L_1 = \frac{3 R_0^2 P_0 - 2 (R_1^2 P_1 - R_2^2 P_2)}{3 (R_2^2 - R_1^2)}$$

---

* The discussion relating to "the strain upon the thread" will subsequently be printed as an appendix to this note.

† This equation is derived as follows: The expression for the relative change in length of fiber, from Virgile (page 12, Notes on the Construction of Ordnance, No. 9) is:

$$+\frac{1}{E}\left(q - \frac{t}{3} + \frac{p}{3}\right)$$

In this we substitute:

$$q = \frac{P_0 R_0^2}{R_2^2 - R_1^2}$$

The values previously deduced for the normal pressures in the state of action (section near breech of tube) are as follows:

$$P_0 = 24.764 \qquad P_1 = 18.293 \qquad P_2 = 9.248$$

which, being substituted in equation (34), give, by reduction,

$$L_1 = 9.99 \text{ tons per square inch.}$$

This is a comparatively low value, but it does not take into account the torsional strain in the angle of jacket at breech of tube due to the difference of tangential displacement of the interior fibers of the jacket when the system is in action on the opposite sides of a right plane through this angle. To diminish the amount of this torsional strain the shrinkage of hoop B_{10} has been made comparatively light, as already shown.

CHANGES IN LENGTH OF TUBE AND JACKET DUE TO SHRINKAGE.

Theoretical rule.* Relative *increase* in length of tube equals one-third the relative tangential compression of bore; and relative *decrease* in length of jacket equals one-third the relative tangential extension of its exterior cylindrical surface.

Confine application of rule to changes of lengths induced by the assemblage of tube and jacket alone since experiment† has shown that when the hoops are applied the tube and jacket will take up practically the same increase of length.

The following is required:

(1) Shrinkage and constants given deduce the normal pressure at the contact surface due to the shrinkage.

(2) Find relative tangential compression of bore of tube and extension of exterior cylindrical surface of jacket produced by that pressure.

(3) Take one-third of these respective values with a contrary sign to express the relative changes in length.

The formulas for application are as follows:

---

and from equations (5) and (6), page 6, Notes on the Construction of Ordnance, No. 6,

$$t = \frac{P_1 R_1^2 - P_2 R_2^2}{R_2^2 - R_1^2} + \frac{R_2^1 R_2^2 (P_1 - P_2)}{R_2^2 - R_1^2} \frac{1}{r^2} \qquad p = -\frac{P_1 R_1^2 - P_2 R_2^2}{R_2^2 - R_1^2} + \frac{R_1^2 R_2^2 (P_1 - P_2)}{R_2^2 - R_1^2} \frac{1}{r^3}$$

The reduction gives, adopting the nomenclature from Clavarino,

$$\frac{d \Delta h_1}{dh_1} = \frac{1}{E} \frac{3 R_0^2 P_0 - 2 (R_1^2 P_1 - R_2^2 P_2)}{3 (R_2^2 - R_1^2)}$$

If L_1 represent the resistance per unit of area, we have

$$L_1 = \frac{d \Delta h_1}{dh_1} E_1$$

Whence, by combination with the preceding equation, we obtain equation (34), given above, in which L_1 may be taken to represent the load corresponding with the elongation induced, or it is the resistance of the metal to elongation which maintains the equilibrium of the forces.

* The theoretical rule is given by Virgile. The formulas here used, which are in accord with that rule, depend upon Clavarino's formulas with the omission of the factor $q = \frac{P R^2 - P' R'^2}{R'^2 - R^2}$ and using instead, $q = o$.

† See summary table of results of hooping test for this gun. (Notes on the Construction of Ordnance, No. 32.)

First. For the pressure (see formula (18) for the form of the equ tion), $P_2'=o$):

$$\varphi=\frac{(4\,R_0^2+2\,R_0^2)\,\overline{P}_1}{3\,(R_1^2-R_0^2)\,E_0}+\frac{(4\,R_2^2+2\,R_1^2)\,P_1}{3\,(R_2^2-R_1^2)\,E_1}$$

from which

$$(35)\;.\;.\;\overline{P}_1=\frac{3\,(R_1^2-R_0^2)\,E_0\;.\;3\,(R_2^2-R_1^2)\,E_1\;.\;\varphi_1}{3\,(R_2^2-R_1^2)\,E_1\,(4\,R_0^2+2\,R_{12})+3\,(R_{12}-R_0^3)\,E_0\,(4\,R_2^2+2\,R}$$

Second. For relative tangential compression of bore of tube:

$$(36)\;.\;.\;.\;.\;.\;.\;.\;.\;\frac{\varDelta R_0}{R_0}=-\frac{2\,R_1^2\,\overline{P}_1}{(R_{12}-R_0^2)\,E_0}$$

Third. For relative tangential extension of exterior cylindrical surf of jacket:

$$(37)\;.\;.\;.\;.\;.\;.\;.\;.\;.\;\frac{\varDelta R_0}{R_2}=\frac{2\,R_1^2\,\overline{P}_1}{(R_2^2-R_{12})\,E_1}$$

Section at breech of tube.—With $\varphi_1=0.00078051$, we find:

$$\overline{P}_1=2.0133$$

$$\frac{\varDelta R_0}{R_0}=0.00062441 \qquad \tfrac{1}{3}=0.000208$$

$$\frac{\varDelta R_2}{R_2}=0.0001561 \qquad \tfrac{1}{3}=0.000052$$

The chamber section.—With $\varphi_1=0.00085594$, we find:

$$P_1=2.3373$$

$$\frac{\varDelta R_0}{R_0}=0.00062606 \qquad \tfrac{1}{3}=0.0002087$$

$$\frac{\varDelta R_2}{R_2}=0.0002988 \qquad \tfrac{1}{3}=0.0000996$$

Section from front of chamber to rear of shoulder on jacket.—With 0.00085594, we find:

$$\overline{P_1}=2.7352$$

$$\frac{\varDelta R_0}{R_0}=0.00058693 \qquad \tfrac{1}{3}=0.0001956$$

$$\frac{\varDelta R_2}{R_2}=0.00026901 \qquad \tfrac{1}{3}=0.00008967$$

Section embracing shoulder on jacket.—With $\varphi_1=0.00085594$, we

$$P^1=2.8786$$

$$\frac{\varDelta R_0}{R_0}=0.0006177 \qquad \tfrac{1}{3}=0.0002059$$

$$\frac{\varDelta R_2}{R_2}=0.00023824 \qquad \tfrac{1}{3}=0.0000794$$

Section embracing screw-thread on jacket.—With $\varphi_1=0.00085594$, we find:

$$\overline{P}_1=2.2831$$

$$\frac{\varDelta R_0}{R_0}=0.00047434 \qquad \tfrac{1}{3}=0.000158$$

$$\frac{\varDelta R_2}{R_2}=0.0003816 \qquad \tfrac{1}{3}=0.0001272$$

From which we derive the following:

Section of gun.	Length of section.	Extension of tube.		Contraction of jacket.	
		Relative.	Absolute.	Relative.	Absolute.
	Inches.	*Thousandths.*	*Inch.*	*Thousandths.*	*Inch.*
At breech of tube	4.5	.208	0.000936	.052	0.000234
Over chamber	41.5	.2087	0.008661	.0996	0.004133
Front of chamber to rear of shoulder on jacket	33.0	.1956	0.006455	.0897	0.002960
Shoulder on jacket	3.0	.2059	0.000618	.0794	0.000238
Screw	8.5	.158	0.001343	.1272	0.001081
Totals	90.5	....	0.018013	....	0.008646

Then, by the theory, when the jacket is shrunk on—

The tube will be extended .... = 0.018
The jacket will be contracted .... = 0.0086

Sum .... = 0.0266

The hooping experiment of the chamber section proved that as regards the extension of the tube the theoretical rule is practically correct. With regard to the contraction in length of jacket the experiment showed that it was much less than the rule would indicate. But the experiment was not conclusive on this point, and the shrinkage then used was only about one-half of the present. On the whole it is estimated that the relative contraction in length of the jacket will in this case be about *one-eighth* the relative extension of its exterior cylindrical surface.

Considering the distance, 86 inches, between the two shoulders on the tube against which we wish the jacket to fit closely without strain, we find:

Inches.
Extension of tube$=0.018013-0.000936$ .... $=0.0171$
Contraction of jacket$=\tfrac{3}{8}\,(0.008646-0.000234)$ .... $=0.0031$

Sum .... $=0.0202$

Hence if the finished length in the jacket between these shoulders is made 86 inches, the finished length on tube should be at least 0.02 of an inch less, or 85.98 inches.

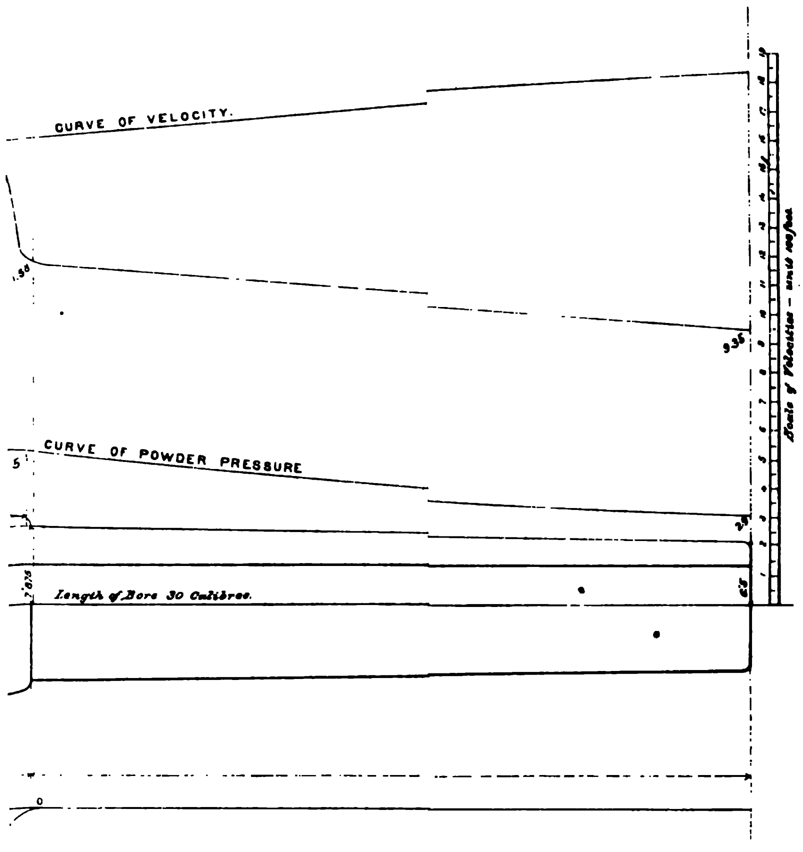
NOTE.—The fixed dimensions and allowances prescribed in this connection for the actual construction of the gun are as follows:

	Inches.
Length of jacket from front face to first shoulder	86.00
Corresponding length on tube	85.96
Length of short counterbore in jacket	4.50
Corresponding length on tube	4.49

which gives a total allowance of 0.05 of an inch on length of tube within jacket over the whole length of 90.5 inches.

R. BIRNIE, JR.,
Lieutenant of Ordnance.

PLATE I.


CURVE OF VELOCITY.
1.58
9.35
CURVE OF POWDER PRESSURE
5
2.9
7.875
Length of Bore 30 Calibres.
6.5
0
1
2
3
4
5
6
7
8
9
10
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13
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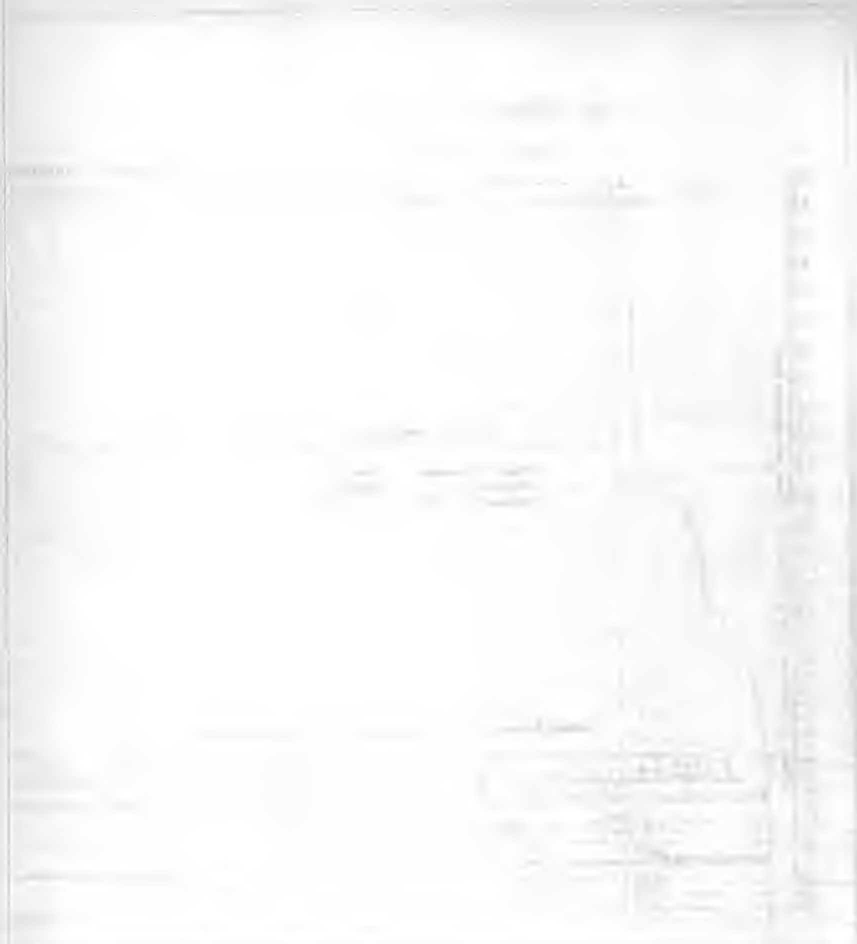
15
16
17
18
19
Scale of Velocities – units 100 feet



APPENDIX 34.

TABLES OF FORGINGS FOR 8, 10, 12, AND 16 INCH STEEL GUNS.

By Lieut. F. E. Hobbs, Ordnance Department.

Office of Inspector of Ordnance, U. S. A.,
Midvale Steel Works,
Philadelphia, Pa., September 23, 1885.

The Chief of Ordnance, *U. S. Army,*
Washington, D. C.:

Sir: In obedience to your instructions I have prepared, and have the honor to transmit herewith, tables showing, as nearly as can be now determined, the dimensions and weights of the forgings required in the construction of 8-inch, 10-inch, 12-inch, and 16-inch steel guns; there is given also the rough finished dimensions and weights of the forgings as they should be delivered by the steel-makers, and the approximate dimensions and weights of the rough forgings and the ingots to be used.

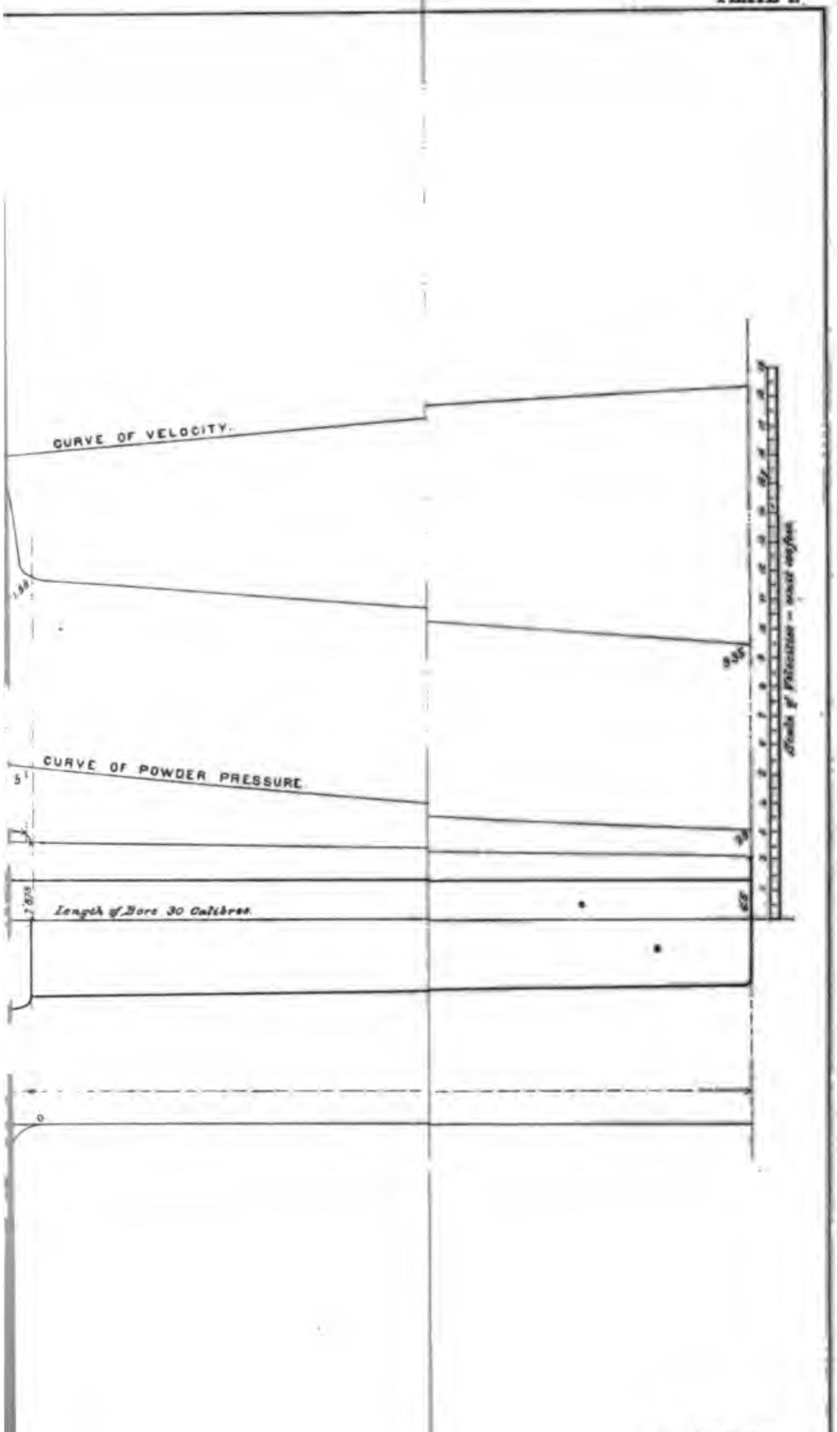
Very respectfully, your obedient servant,

F. E. HOBBS,
Lieutenant of Ordnance.

Forgings for 8-inch B. L. steel gun.

Nature of piece.	Finished.				Rough finished as delivered by steel-makers.			
	Interior diameter.	Exterior diameter.	Length.	Weight.	Interior diameter.	Exterior diameter.	Length.	Weight.
	Inches.	*Inches.*	*Inches.*	*Tons.*	*Inches.*	*Inches.*	*Inches.*	*Tons.*
Tube	8.0 9.5	13.00 15.75 15.00	261.5	4.01	7.75	13.5 16.0 15.25	264.0	4.70
Jacket	15.0 10.5	20.5 23.5	108.25	3.70	14.75 10.25	23.75	110.0	4.05
				Pounds.				*Pounds.*
5 common hoops	23.5	30.0	16.0	6,160	23.25	30.25	16.25	6,708
1 common hoop	23.5	29.5	9.75	698	23.25	29.75	10.00	772
1 common hoop	20.25	26.25	20.50	1,280	20.00	26.50	20.75	1,402
1 common hoop	16.25	20.25	11.75	383	16.00	20.50	12.00	442
1 common hoop	16.75	22.25	19.00	912	16.50	22.50	19.25	1,008
1 common hoop	16.75	21.50	19.00	772	16.50	21.75	19.25	865
Trunnion hoop	23.50	31.00	13.50	1,500	....	....	....	1,650
Total weight of rough finished forgings	....	....	....	....	....	....	....	32,445

PLATE I.



Appendix 33—1885.

APPENDIX 34.

S OF FORGINGS FOR 8, 10, 12, AND 16 INCH STEEL GUNS.

BY LIEUT. F. E. HOBBS, ORDNANCE DEPARTMENT.

)FFICE OF INSPECTOR OF ORDNANCE, U. S. A.,
MIDVALE STEEL WORKS,
Philadelphia, Pa., September 23, 1885.

OF ORDNANCE, *U. S. Army*,
Washington, D. C.:

obedience to your instructions I have prepared, and have ɔ transmit herewith, tables showing, as nearly as can be now , the dimensions and weights of the forgings required in the ı of 8-inch, 10-inch, 12-inch, and 16-inch steel guns; there o the rough finished dimensions and weights of the forgings uld be delivered by the steel-makers, and the approximate and weights of the rough forgings and the ingots to be

respectfully, your obedient servant,

F. E. HOBBS,
Lieutenant of Ordnance.

Forgings for 8-inch B. L. steel gun.

piece.	Finished.				Rough finished as delivered by steel-makers.			
	Interior diameter.	Exterior diameter.	Length.	Weight.	Interior diameter.	Exterior diameter.	Length.	Weight.
	Inches.	*Inches.*	*Inches.*	*Tons.*	*Inches.*	*Inches.*	*Inches.*	*Tons.*
	8.0 9.5	13.00 15.75 15.00	261.5	4.01	7.75	13.5 16.0 15.25	264.0	4.70
	15.0 10.5	20.5 23.5	108.25	3.70	14.75 10.25	23.75	110.0	4.05
				Pounds.				*Pounds.*
	23.5	30.0	16.0	6,160	23.25	30.25	16.25	6,708
	23.5	29.5	9.75	693	23.25	29.75	10.00	772
	20.25	26.25	20.50	1,280	20.00	26.50	20.75	1,402
	16.25	20.25	11.75	383	16.00	20.50	12.00	442
	16.75	22.25	19.00	912	16.50	22.50	19.25	1,008
	16.75	21.50	19.00	772	16.50	21.75	19.25	865
	23.50	31.00	13.50	1,500				1,650
ht of rough forgings								32,445

Forging for 8-*inch B. L. steel gun*—Continued.

Nature of piece.	Of rough forging.			Of ingot.			Excess of weight of ingot over weight of rough forging.	Number of times area of cross-section of ingot exceeds area of cross-section of rough forging.	Part of weight of ingot used for rough forgings.
	Exterior diameter.	Length.	Weight.	Cross-section.	Height.	Weight.			
	Inches.	*Inches.*	*Tons.*	*Inches.*	*Inches.*	*Tons.*	*Per ct.*		*Per ct.*
Tube	14.50 17.25 16.50	272.0	7.65	37 diameter or 33 square.	103.0 100.0	14.0	83.0	4.13 4.18	54.6
Jacket	25.0	118.0	7.35	50 diameter or 45 square.	54.0 52.0	13.45	83.0	4.00 4.13	54.7

Forgings for 10-*inch B. L. steel gun.*

Nature of piece.	Finished.				Rough finished as delivered by steel-makers.			
	Interior diameter.	Exterior diameter.	Length.	Weight.	Interior diameter.	Exterior diameter.	Length.	Weight.
	Inches.	*Inches.*	*Inches.*	*Tons.*	*Inches.*	*Inches.*	*Inches.*	*Tons.*
Tube	10.0 12.0	16.5 19.7 18.0	325.7	7.75	9.75	16.75 19.95 18.25	328.2	8.54
Jacket	18.0 13.5	24.7 27.7	134.0	6.2	17.75 13.25	27.95	135.25	6.65
				Pounds.				*Pounds.*
5 common hoops	33.0	39.5	20.0	10,080	32.75	39.75	16.25	11,100
6 common hoops	27.7	33.0	19.0	8,050	27.45	33.25	16.25	9,600
1 common hoop	27.7	37.5	15.0	2,145	27.62	37.75	15.25	3,128
1 common hoop	24.7	32.5	21.0	2,100	24.5	32.75	21.25	2,273
1 common hoop	24.7	31.0	21.0	1,688	24.5	31.25	21.25	1,736
2 common hoops	19.7	24.7	16.5	1,640	19.5	25.00	16.75	1,834
1 common hoop	19.7	26.0	18.0	1,160	19.5	26.25	18.25	1,260
1 common hoop	19.7	25.5	18.0	1,056	19.5	25.75	18.25	1,100
1 common hoop	19.7	24.5	18.0	905	19.5	24.75	18.25	950
Trunnion hoop	33.0	39.5	16.5	2,636				2,785
Total weight of rough-finished forgings								69,223

Nature of piece.	Of rough forging.			Of ingot.			Excess of weight of ingot over weight of rough forging.	Number of times area of cross-section of ingot exceeds area of cross-section of rough forging.	Part of weight of ingot used for rough forging.
	Exterior diameter.	Length.	Weight.	Cross-section.	Height.	Weight.			
	Inches.	*Inches.*	*Tons.*	*Inches.*	*Inches.*	*Tons.*	*Per ct.*		*Per ct.*
Tube	18.0 21.2 19.5	341.2	13.66	42 diameter or 38 square.	140.0 136.0	25.0	83.0	3.92 4.03	54.6
Jacket	29.2	148.25	12.56	58 diameter or 51 square.	69.0 70.0	23.0	83.0	3.94 3.88	54.6

Forgings for 12-inch B. L. steel gun.

Nature of piece.	Finished.				Rough finished as delivered by steel-makers.			
	Interior diameter.	Exterior diameter.	Length.	Weight.	Interior diameter.	Exterior diameter.	Length.	Weight.
	Inches.	*Inches.*	*Inches.*	*Tons.*	*Inches.*	*Inches.*	*Inches.*	*Tons.*
Tube	12.0 14.5	19.8 23.6 21.8	391.0	13.22	11.75	20.05 23.85 22.05	394.0	14.51
Jacket	21.8 16.0	29.5 33.0	160.9	10.2	21.55 15.50	35.75 33.25	162.5	11.28
				Pounds.				*Pounds.*
5 common hoops	39.80	48.0	23.0	18,435	39.50	48.25	23.25	19,775
6 common hoops	33.00	39.8	22.0	14,628	32.75	40.05	22.25	15,888
1 common hoop	33.00	45.0 39.8	22.0	3,694	32.75	45.25 40.05	22.25	3,957
1 common hoop	29.50	39.0	25.5	3,715	29.85	39.25	25.75	3,948
1 common hoop	29.50	37.0	25.5	2,847	29.25	37.25	25.75	3,066
2 common hoops	23.60	29.5	18.0	2,525	23.35	29.75	18.25	2,778
1 common hoop	23.60	31.2	22.0	1,992	23.35	31.45	22.25	2,210
1 common hoop	23.60	30.5	22.0	1,762	23.35	30.75	22.25	1,993
1 common hoop	23.60	29.75	22.0	1,563	23.35	30.00	22.25	1,766
Trunnion hoop	39.80	49.20	19.8	4,350	....	....	....	4,700
Total weight of rough-finished forgings	....	....	....	....	....	....	....	117,851

Nature of piece.	Of rough forging.			Of ingot.			Excess of weight of ingot over weight of rough forging.	Number of times area of cross-section of ingot exceeds area of cross-section of rough forging.	Part of weight of ingot used for rough forging.
	Exterior diameter.	Length.	Weight.	Cross-section.	Height.	Weight.			
	Inches.	*Inches.*	*Tons.*	*Inches.*	*Inches.*	*Tons.*	*Perct.*		*Perct.*
Tube	21.75 25.50 23.50	407.0	23.75	50 diameter. or 45 square.	160.0 155.0	40.0	68.4	3.85* 3.97	59.4
Jacket	38.0 35.0	175.5	22.0	68 diameter or 60 square.	83.0 84.0	38.0	72.7	3.20* 3.16	57.9
						Alternate design.			
	Forged on mandrel.		19.04	75 diameter or 66 square.	71.0 72.0	40.0	82.0	3.89* 3.84	55.0

* Greatest cross-section of rough forging used in this comparison.

Forgings for 16-inch B. L. steel gun.

Nature of piece.	Finished. Interior diameter.	Finished. Exterior diameter.	Finished. Length.	Finished. Weight.	Rough finished as delivered by steel makers. Interior diameter.	Rough finished as delivered by steel makers. Exterior diameter.	Rough finished as delivered by steel makers. Length.	Rough finished as delivered by steel makers. Weight.
	Inches.	*Inches.*	*Inches.*	*Tons.*	*Inches.*	*Inches.*	*Inches.*	*Tons*
Tube	16.0 19.0	22.0 29.0 28.0	521.0	22.92	15.75	22.25 29.25 28.25	525.0	25.27
Jacket	28.0 21.0	40.0	223.2	19.0	27.75 20.5	40.25	227.0	21.16
				Pounds.				*Pounds.*
Sleeve	40.0	47.5	124.2	18,184	39.75	47.75	124.45	19,436
1 common hoop	55.3	66.5	37.1	11,291	55.05	66.75	37.35	11,875
3 common hoops	55.3	64.5	37.0	27,292	55.05	64.75	37.25	29,046
1 common hoop	46.5	55.3	48.2	9,633	46.25	55.55	48.45	10,173
1 common hoop	47.5	55.3	24.0	4,293	47.25	55.55	24.25	4,[illegible]
2 common hoops	47.5	55.3	34.0	12,165	47.25	55.55	34.25	13,[illegible]
1 common hoop	47.5	55.3	30.0	5,366	47.25	55.55	30.25	5,734
1 common hoop	48.3	55.3	21.0	3,397	48.05	55.55	21.25	3,[illegible]
1 common hoop	39.0	47.0	36.0	5,526	38.75	47.25	36.25	5,912
1 common hoop	40.0	49.8 48.3	49.0	8,209	39.75	50.05 48.55	49.25	8,715
1 common hoop	48.3	60.0	26.0	7,340	48.05	60.25	26.25	7,730
1 common hoop	37.0	51.0	40.5	11,132	36.75	51.25	40.75	11,[illegible]
1 common hoop	37.0	48.0	40.5	8,448	36.75	48.25	40.75	8,[illegible]
1 common hoop	29.6	38.4	35.6	4,753	29.35	38.65	35.85	5,057
2 common hoops	28.0	37.0	36.0	9,397	27.75	37.25	36.25	9,[illegible]
1 common hoop	27.0	36.0	36.0	4,553	26.75	36.25	36.25	4,[illegible]
1 common hoop	26.0	34.0	36.0	3,855	25.75	34.25	36.25	4,125
common hoop	25.0	32.0	36.0	3,204	24.75	32.25	36.25	3,457
1 common hoop	24.0	30.5	36.0	2,845	23.75	30.75	36.25	3,[illegible]
1 common hoop	23.0	29.5	36.0	2,741	22.75	29.75	36.25	2,972
1 common hoop	22.0	28.0	36.0	2,409	21.75	28.25	36.25	2,[illegible]
Trunnion hoop	55.3	66.5	42.0	12,782	55.05	66.75	42.25	13,465
Total weight of rough finished forgings								294,061

Nature of peice.	Of rough forging. Exterior diameter.	Of rough forging. Length.	Of rough forging. Weight.	Of ingot. Cross-section.	Of ingot. Height.	Of ingot. Weight.	Excess of weight of ingot over weight of rough forging.	Number of times area of cross-section of ingot exceeds area of cross-section of rough forging.	Part of weight of ingot used for rough forging.
	Inches.	*Inches.*	*Tons.*	*Inches.*	*Inches.*	*Tons.*	*Per ct.*		*Per ct.*
Tube	24.0 31.0 30.0	538.0	45.17	62 diameter or 55 square.	194.0 193.0	75.0	66.0	4.00 4.00	60.2
Jacket	42.0	240.0	42.15	75 diameter or 66 square.	123.0 125.0	69.0	64.2	3.20 3.15	[illegible]
						Alternate design.			
				80 diameter or 71 square.	121.0 121.0	77.5	83.8	3.63 3.63	54.4
	Forged on mandrel.		32.5	75 square	108.0	77.5	83.8	4.00	54.4

APPENDIX 35.

PROPOSED 12-INCH BREECH-LOADING STEEL RIFLE 40 TONS.

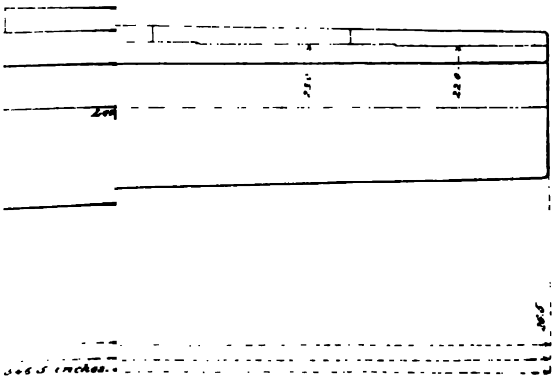
BY CAPT. CHAS. S. SMITH, ORDNANCE DEPARTMENT

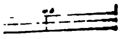
(1 PLATE.)

PLATE I.

NS

STEEL





Chas S. Smith
Captain of Ordnance,
Principal Assistant

APPENDIX 36.

INSPECTION REPORT OF 8-INCH EXPERIMENTAL BANDED CORED SHOT.

BY LIEUT. WILLIAM CROZIER, ORDNANCE DEPARTMENT.

DECEMBER 2, 1884.

SIR: I have the honor to submit herewith inspection report of 8-inch experimental banded cored shot:

The bands were applied as represented in the accompanying blue print, except that the grooves in some of the projectiles are only .1 inch deep. These are marked with a small "s" after the number designating the character and position of the band.

The bands were hammered into place by hand, those which gave the best results having been first finished to proper section and then bent in a press until they would pass into the grooves. With the narrow ones the bending was omitted and a shallow groove was cut in the under side of the band to facilitate the flow of the metal into the undercut portions of the grooves in the projectiles.

In obedience to your instructions, I determined the center of percussion of the shot, exclusive of the head, with reference to a transverse axis intersecting the axis of the shot at the base of the head. This point I first found by calculation, determining separately the values of the expressions Σvr^2 for the different geometrical solids composing the portion under consideration, thus obtaining $v'k'^2$. To obtain these separate values I used the formulas $\Sigma vr^2 = \int \pi y^2 x^2 dx$ and $v'k'^2 = v'(k_{,1}{}^2 + d^2)$, the volumes all being of revolution about the axis of the shot taken as the axis of X. The separate volumes determined similarly from the formula—

$$v = \int \pi y^2 dx$$

gave by summation the value of V, from which and the values of $v'k'^2$ above, k was determined. The position of the center of gravity was found in the usual manner by equality of moments, and the length of the equivalent simple pendulum by the formula

$$1 = \frac{k_1{}^2 + e^2}{e} = \frac{k^2}{e}$$

with the result 1=7.″33=distance of center of percussion desired from axis of suspension. In the above calculations the density and diameter were considered uniform, the latter 8″, which assumptions were permissible in view of the necessity for obtaining the required position with sufficient accuracy only to insure its being included within the band.

It having subsequently become necessary to cut up one of the projectiles, the same point was determined experimentally by vibrating the portion considered, using the formula—

$$l = \frac{l^1 . 60^2}{n^2}$$

in which—

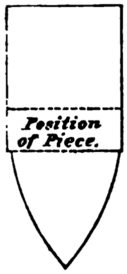
l=length sought.
l′=simple second pendulum at Watertown Arsenal=3.25981 feet.
n=number of vibrations in one minute=138.

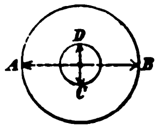
Resulting in the value—

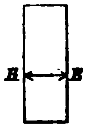
$$l' = 7''.43$$

0″.1 greater than the one above, as was to have been expected from the assumptions made.

To determine the specific gravity, using much larger fragments than can be weighed on the delicate scales usually employed for that purpose, I first tried the ordinary method of weighing in air and in water a piece of the cylindrical portion, weighing about 50 pounds. But the weighing apparatus not being sufficiently accurate to give satisfactory results, I took a piece which, by a little work, was given the form of a simple volume, and weighed it with the following results:







A B= 7.″909
C D= 3.″186
B E= 3.″461
v=142.443 cubic inches.

Subtracting volume of two small holes=

v^1=.9713 $v-v^1$= V=141.4717
W= 36.9839 pounds.

$$\text{Specific gravity} = S = \frac{W \times 1728}{V \times 62.355}$$

log. W= 1.567596
log. 1728= 3.237544
a. c. log. V= 7.849331
a. c. log. 62.355= 8.205129

20.859600
20.

log. S= .859600
S=7.237

I make the following computation of the volume of the shot using for the ogival parts the formula and numbers given in Table IX from the Ordnance Office.

Volume of head (up to true base of ogival) = H .3 log. D + log. c = log. H.

$$\begin{array}{rr}
\text{Log. D } (=7''.97) = & .901458 \\
 & 3 \\
\hline
 & 2.704374 \\
\text{log. } c = & \bar{1}.760573 \\
\hline
\text{log. H} = & 2.464947
\end{array}$$

H = 291.70 cubic inches.

Volume of cylinder in rear of true base of ogival = C = π R² × 9.38.

$$\begin{array}{rr}
\text{Log. R } (= \tfrac{7.93}{2} = 3.965) = & .598243 \\
 & 2 \\
\hline
 & 1.196486 \\
\text{log. } 9.38 = & .972203 \\
\text{log. } \pi = & .497150 \\
\hline
\text{log. C} = & 2.665839
\end{array}$$

C = 463.27 cubic inches.

Volume of hemispherical part of core = $\frac{2}{3} \pi r^3$ = P.

$$\begin{array}{rr}
\text{Log. } r\ (= 1.75) = & .243038 \\
 & 3 \\
\hline
 & .729114 \\
\text{log. } \pi = & .497150 \\
\text{log. } \tfrac{2}{3} = \text{log. } .6666 = & \bar{1}.823865 \\
\hline
\text{log. P} = & 1.050129
\end{array}$$

P = 11.22 cubic inches.

Volume of ogival part of core considered as complete = o.

$$\begin{array}{lrr}
 & \text{Log. } o = 3 \text{ log. } d + \text{log. } c & \\
 & \text{Log. } d\ (= 3.5) = & .544068 \\
 & & 3 \\
\hline
 & & 1.632204 \\
c \text{ by interpolation} = 1.0876 & \text{log. } c = & .036470 \\
\hline
 & \text{log. } o = & 1.668674
\end{array}$$

o = 46.63 cubic inches.

$$\begin{array}{lrr}
 & \text{H} = & 291.70 \\
 & \text{C} = & 463.27 \\
\hline
 & & 754.97 \\
\text{P} = 11.22 & & \\
o = 46.63 & & \\
\hline
57.85 & & 57.85 \\
\hline
 & & 697.12
\end{array}$$

Adding .88 cubic inches for head of plug and very small parts neglected at end of core and head of cylinder .... .88

V = 698.00 cubic inches.

Deducing the specific gravity necessary to give the established weight, 180 pounds—

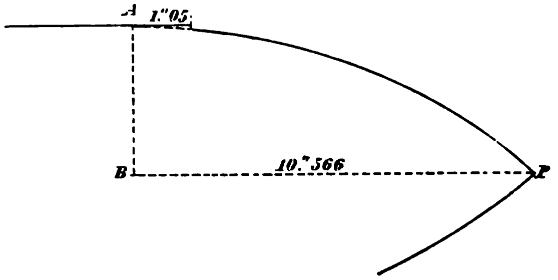
$$S=\frac{180\times 1728}{698\times 62.355}$$

$$\begin{array}{rl}
\log.\ 180= & 2.255273 \\
\log.\ 1728= & 3.237544 \\
a.\ c.\ \log.\ 698= & 7.156145 \\
a.\ c.\ \log.\ 62.355= & 8.205129 \\
\hline
 & 20.854091 \\
 & 20. \\
\hline
\log.\ S= & .854091 \\
S= & 7.146
\end{array}$$

which is lower than the specific gravities usually reported.

Assuming an average specific gravity of 7.21, the above volume would give a weight of 181.6 pounds. In view of which I would suggest that either the established weight be increased to about 182 pounds or the dimensions of the shot be modified.

The specific gravity determined above gives a weight of 182.3 pounds.



I have been unable to find agreement between the drawing of the shot and my instructions as to its manufacture. The instructions require the head to be moved bodily back 1."05, the form about the head being then as indicated in the sketch, "the slight shoulder thus formed to be smoothed off." The equation of the circle AP is—

$$(x-x')^2+(y-y')^2=R^2$$

$$\left.\begin{array}{l} x'=0 \\ y'=-\left(16-\frac{7.97}{2}\right)=-12.015 \end{array}\right\}\text{Coördinates of center.}$$

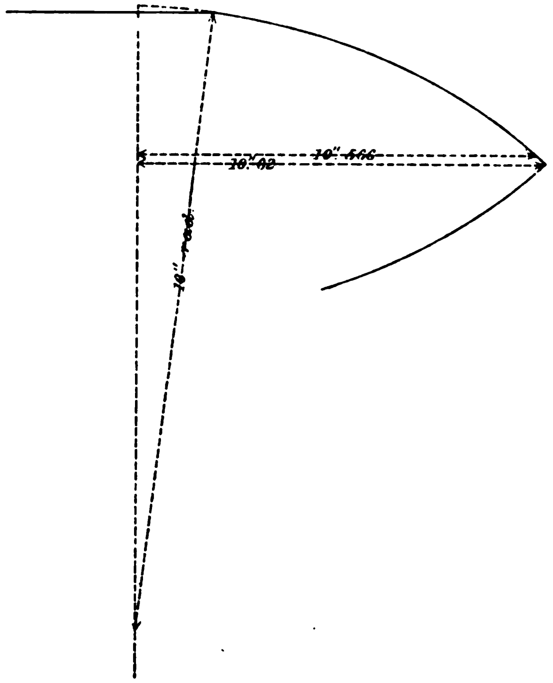
$$R=\text{radius}=16\ \therefore$$

$$x^2+(y+12.015)^2=16^2$$

making $y=0$, we deduce $x=10.''566$ for the distance BP, which does not agree with the distance given on the drawing, that being 10."62, resulting from a position of the circle indicated below.

The height of the shoulder required in my instructions from you could be very easily indicated in the drawing, being ."035. I cannot see why the shoulder would not be a great disadvantage ballistically, and would recommend a change in the required form, to correspond with the second sketch above.

Since commencing the manufacture of these projectiles, four large shot-lathes have been added to the plant, and various improvements have been made in the patterns, iron, and process of finishing, and should there be more of them ordered they could be produced more expeditiously and economically and of more uniform weight and dimensions.

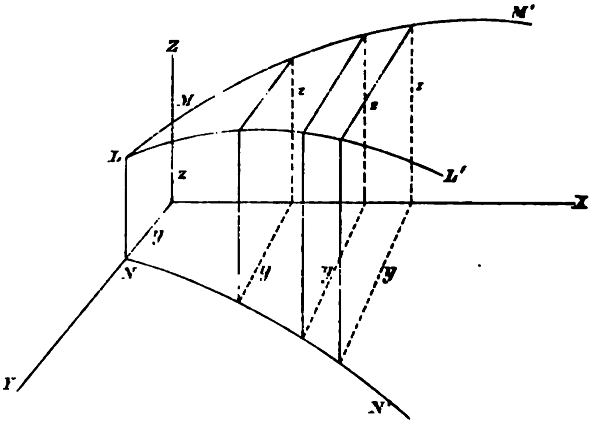


In the preceding determinations no methods of any particular novelty or interest were used, unless one may have been that of calculating the centers of gravity, moments of inertia, and in general all elements necessitating the finding of the limit of the sum of an infinite number of products of two functions of the same variable. The principle involved may be stated as follows:

The limit of the sum of all the products of two functions of the same variable as $f(x)$, and $\varphi(x)$ for all values of x between two given limits; is equal to the integral between those limits of $f(x) \times \varphi(x) \times dx$, or to $\int_a^b f(x)\, \varphi(x)\, dx$.

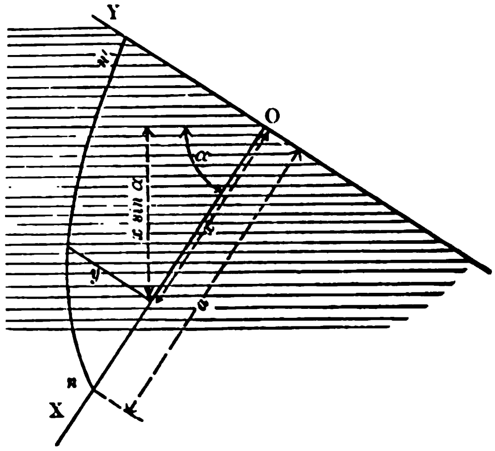
To prove which; construct in the coördinate plane XZ the curve whose equation is $z = f(x)$, and in the plane XY that whose equation is $y = \varphi(x)$, then one of the products $f(x) \times \varphi(x)$ would be a rectangle yz, and all of the products between limits corresponding to two values a and b of x would compose the volume bounded by the planes XZ and XY, the two cylinders whose directrices are MM′ and NN′, respectively, intersecting in LL′, and two planes parallel to YZ distant from it a and b, respectively.

From calculus we know that the partial differential of such a volume with respect to x is equal to the area of a section perpendicular to the axis of x multiplied by dx, which is $yzdx$ or $f(x) \times \varphi(x) \times dx$, and that the volume described is equal to $\int_a^b f(x)\times\varphi(x)\times dx$. Hence we see that the facility with which we may obtain the limit of the sum of such products depends upon that with which we may integrate the expression $f(x)\times\varphi(x)\times dx$.



I append a simple example. Let it be required to deduce a general formula for the distance of the center of pressure of a submerged surface from the upper surface of the fluid, measured in the submerged surface.

Suppose such surface to be included between the axis of x and a curve whose equation is $y=f(x)$, which is a general case to which all others may be reduced.



Call the required distance P. We know the total pressure upon a submerged surface to be equal to the weight of a column of the fluid whose base is equal in area to the surface pressed and whose altitude is equal to the distance of the center of gravity of such surface from the upper surface of the fluid. Calling the weight of a unit of volume of the fluid h, the pressure on a single ordinate will be:

$$h\,y\,x\sin\alpha$$

α being angle of inclination of surface, and the total pressure, from our principle:

$$h\int_0^a y\,x\sin\alpha\,dx$$

and its moment with respect to O Y (upper line of surface):

$$Ph\int_0^a y\,x\sin\alpha\,dx$$

The moment of the pressure on a single ordinate with respect to same line is $h\,y\,x\sin\alpha\,x = h\,y\,x^2\sin\alpha$ and the limit of the sum of all these moments $h\int_0^a y\,x^2\sin\alpha\,dx$.

Equating these two values:

$$h\sin\alpha\int_0^a yx^2\,dx = P\,h\sin\alpha\int_0^a yx\,dx$$

Whence:

$$P=\frac{\int_0^a yx^2\,dx}{\int_0^a yx\,dx}$$

A formula not only simple and easy to remember, but easily deduced if the principle is borne in mind.

If the surface be a rectangle $y=b$ and:

$$P=\frac{b\int_0^a x^2\,dx}{b\int_0^a x\,dx}=\frac{\frac{a^3}{3}}{\frac{a^2}{2}}=\tfrac{2}{3}\,a.$$

If a parabola, whose equation is then:

$$y^2=2\,p\,(x+a)$$

$$P=\frac{\int_{x=0}^{x=-a} y\left(\frac{y^4-4pay^2+4p^2a^2}{4p^2}\right)\frac{ydy}{p}}{\int_{x=0}^{x=-a} y\left(\frac{y^2-2pa}{2p}\right)\frac{ydy}{p}}$$

$$=-\frac{4}{7}a,\ \text{since } x=-a \text{ gives } y=0, \text{ and } x=0 \text{ gives } y^2=2\,pa$$

A little consideration will show that the truth of the principle would not be affected if one or both of the functions should become constant.

The newness of the subject of the manufacture of these shot must be my excuse for great apparent diffuseness. I have endeavored to curtail the descriptions as much as possible; in some instances I fear closely approaching the limit of intelligibility.

I am, sir, very respectfully, your obedient servant,

WILLIAM CROZIER,
First Lieutenant of Ordnance.

Maj. F. H. PARKER,
Commanding Watertown Arsenal.

APPENDIX 37.

INSPECTION REPORT OF 8-INCH HOTCHKISS BANDED CORED SHOT.

BY LIEUT. ROGERS BIRNIE, JR., ORDNANCE DEPARTMENT.

(2 plates.)

The following includes, with the reports of inspection, some notes upon the manufacture of the fabrications included, viz:

Two hundred and three supplied under contract dated November 11, 1884, and twenty supplied under order dated January 8, 1885.

A drawing (Plate II) of the shot is appended. The dimensions and data upon which this drawing is based have been determined by the fabrication of the shot in question, and verified by the weights of the finished projectiles compared with the density of the cast-iron. The specific gravity of the iron may vary between 7.15 and 7.30 and retain the finished weight of projectile between the limits 178.0 and 182.75 pounds, corresponding to the allowed variations of — 1 per cent. and + 1½ per cent. from the prescribed average weight of 180 pounds. The weight of the base plug is 1.5 pounds and of the finished band 2.5 pounds. The weight of cast-iron turned off in fitting the band equals (very nearly) the weight of the finished band. Since, practically, the whole variation of weight occurs in the cast-iron portion, due to slight variations in dimensions of unfinished parts, but especially to variations of density in the different lots of castings, it may be stated that the average weight of the cast-iron alone after the cylindrical portion has been finished but not fitted for the band should be 178.5 pounds and the limits 176 to 180.75 pounds.

Plate I gives a drawing of the pattern used for the shot molds; it shows the manner of laying out the pattern to compensate for the shrinkage of the casting. It is arranged to cast the base and curve of head to finished size. The extreme point and cylindrical portion of shot are then the only portions requiring a machine finish. The amount of shrinkage varies with the nature of the iron used, but the following, upon which the drawing is based, may be taken as approximately correct, viz:

	Inches.
Shrinkage on length of head	0.125
Shrinkage on length of body	0.06
Shrinkage on diameter at base of head	0.05

The extreme point shrinks relatively more than the portions of larger diameter and there is a tendency for the casting to become too blunt there. To compensate for this the radius of curve for head of pattern is made greater than that prescribed for the shot, and the two curves, in place, are not parallel, but diverge towards the point. The two centers are taken upon the same vertical line, a prolongation of the diameter at base of head of finished shot.

Upon the diameter of cylindrical portion of shot, which must be machine-finished, the pattern is made three-sixteenths of an inch larger than the finished size, to include allowances for the shrinkage and the surplus metal needed for the finish. This portion of the pattern is joined to the curve of head by a gentle slope to obviate the occurrence of a shoulder in case the shrinkage on the diameter at base of head exceeds the allowance.

The arrangements for the core mold of these shot is similar to that described in Notes on the Construction of Ordnance, No. 26. The sand molds for the core and shot are both oven-dried. The shot are cast point down, and, as before stated, with finished base, only the "riser" is removed at the "chipping" bench. As soon as the metal is poured the casting is "fed" with hot metal poured from time to time from a hand ladle into the riser, and this metal is stirred by an up and down motion of an iron rod, in the hands of a helper, which is thrust down to reach nearly the core mold, but not to touch it. The feeding is continued until the casting is "set." Under this process air-holes or cavities, which are liable to occur near the upper surface of a casting made without feeding, are rarely found, and the hard skin of the natural casting left on the base is believed to be conducive to the strength of the shot.

Pursuant to the usual practice at this foundry, these shot, having a prescribed tenacity of 25,000 pounds per square inch, were cast with metal taken directly from the air-furnace. The following gives a record of the castings and tests of the metal:

Records of castings and tests of metal.

Date.	Castings.									Tests.	
				Charge of iron in percentages.							
	Number cast.	Marks.	Average weight in rough state.	Gore No. 2.	Gore No. 3.	Hudson No. 2 (extra).	Old shot.	Air furnace scrap.	Cupola scrap.	Tenacity.	Density.
1884.											
Nov. 17	2	......	....	24.5	6.6	6.6	17.9	15.9	28.5	30,300	7.2680
22	50	A	179.8	28.3	......	11.8	......	28.3	31.5	28,888	7.1959
Dec. 15	50	B	183.5	25.0	......	......	26.3	24.8	24.8	24,235 26,749	7.3472 7.3332
17	50	C	184.8	38.7	......	19.3	6.1	15.5	20.1	26,928 26,344	7.2789 7.2443
19	50	D	185.2	30.3	......	28.8	6.0	15.1	19.7	29,690 28,522	7.3446 7.2927
22	6	C₇	185.0	24.8	......	14.2	6.5	43.8	10.6	31,363 31,947	7.3479 7.2727
27	29	E	184.8	28.1	......	15.7	......	25.8	30.5	31,416	7.2846

REMARKS.—The cupola scrap includes only broken castings of the best quality of castings. Where two records of tests are given for one lot of castings the first is from the proof bar and the second from the middle wall of shot opposite the greatest diameter of core. Where a single test is given the specimen was taken from the wall of shot as above.

Before casting lot B the two sample shot were finished. They were found to be light in weight, and authority was obtained to increase the length of the shot, which was done by adding ″0.25 to the base of the forward portion of the shot pattern at the "parting line." The remaining castings were made with this pattern and the drawing of the finished shot herewith (Plate II). corresponds to the shot so made. Of the fifty-two castings made with the original pattern, the finished shot weigh between 177 and 179 pounds. Of those made after the length was increased the average weight is 181 pounds nearly, but it may be seen that the density of the metal is uniformly high and above the average of what may be expected in the usual run of manufacture.

In finishing the shot the several operations are as follows: The small cylinder at the point is first turned off and the point finished to conform to the curve of head of shot. The base plug hole is then reamed out and the thread for base plug (eight to the inch) finished. Next the base of the cylindrical portion of shot is finished-turned for a length of about 0.75 inch in a lathe to give a starting place for the circular cutters used in the hydraulic press for finishing the cylinder. The shot is passed twice through the press to make one roughing and one finishing cut.

In fitting the shot for the band the grooves are first roughed out in the lathe with a simple cutting tool and then finished with a tool shaped to include the whole of the portion of the shot covered by the band. The three grooves in the two rear lands under the band intended to prevent the band from turning when the shot is fired are made with a hand tool.

The composition of the band metal is ninety-five parts copper and five parts spelter, the latter being added, as is understood, to increase the soundness of the castings. The castings are made as a simple cylinder or band with sufficient surplus metal to finish on all sides. In order to assemble them on the shot they are faced at the ends and the interior finished to an easy driving fit over the two rear lands on shot. The diameter of the cylinder of shot in rear of band is made slightly smaller than that of the lands named in order to pass the band over it. When the band is on it is hammered down at the ends to give them proper bearings. The exterior of the band is then finished in the lathe.

RECORD OF CASTINGS.

Bands for 8-inch Hotchkiss projectiles.

Date.		No. cast.	Charge of metals.				Percentage of spelter.	Average rough weight of castings.	Loss of metal charged.
			Copper.	Spelter.	Composition.	Total weight.			
1884.			*Pounds.*	*Pounds.*	*Pounds.*	*Pounds.*		*Pounds.*	*Pounds.*
Dec.	1	22	125.0	6.25	....	131.25	4.76	4.7	0.75
	2	30	178.0	9.0	20.0	207.0	4.81	4.7	2.0
	3	30	125.0	7.0	60.0	192.0	5.3	4.7	3.0
	4	15	90.0	5.0	25.0	120.0	5.26	4.7	2.5
	5	30	120.0	6.5	50.0	176.5	5.13	4.7	3.5
	6	30	136.0	7.5	30.0	173.5	5.22	4.7	3.5
	8	30	122.0	7.0	60.0	189.0	5.42	4.7	3.0
	9	15	48.0	2.5	40.0	90.5	4.95	4.7	2.5
	31	22	158.0	8.0	15.0	181.0	4.82	4.7	3.0

The base plugs of wrought iron are rough-forged to shape in a die using a small steam-hammer, and then finished and threaded in a lathe. To insure a tight fit the thread in the base plug hole of shot is sized, for the finish, with a screw tap corresponding to the finished thread on the plug.

The following give the summary records of the inspection:

Inspection report of 8-inch ogival-headed Hotchkiss projectiles for breech-loading rifles made for the United States Ordnance Department by West Point Foundry Association, at West Point Foundry, under contract of the Chief of Ordnance U. S. Army, dated November 11, 1884.

Subject of measurement.	Prescribed dimensions.	Allowed variations.	
PROJECTILE.	*Inches.*	*Inch.*	*Pounds.*
Length of cylindrical portion of body to band	*7.35 7.60	+0.15	....
Length of head	8.902	−0.17	....
Length of base for band	2.048	±0.01	....
Length of base in rear of band	.5	±0.01	....
Length of base in rear of cylindrical portion	.25	±0.05	....
Total length of projectile	*19.05 19.3	±0.19	....
Diameter of cylindrical portion	7.95	±0.01	....
Diameter of base in rear of band	7.86	±0.01	....
Radius of head	12.0	±0.05	....
Thickness of bottom	2.3	±0.1	....
Length of interior cavity	10.25	±0.1	....
Thickness of walls at 4.05 inches from base	2.225	±0.1	....
Eccentricity of axis of interior cavity	....	0.1	....
Diameter of screw-plug hole	1.5	±0.01	....
Pitch of thread on screw-plug hole	8 to inch.	....	....
Length of thread on fuse (or screw-plug) hole	2.3	±0.1	....
Number of cannelures under band	4	....	....
Depth of cannelures under band	0.116 to 0.149		....
Width of cannelures	0.225 to 0.52		....
Weight of projectile, including plug and without band	177.5	....	+2.7 −1.8
BAND.			
Length of band	2.048	±0.01	....
Exterior diameter of band	8.15	±0.01	....
Interior diameter of band (maximum)	7.862	±0.01	....
Thickness of band	0.144	±0.01	....
Radius of curve at front	4.075	....	....
Weight of band	2.5	....	....
Weight of band and projectile	180.0	....	+2.7 −1.8

Number of 8-inch Hotchkiss projectiles examined	213	Weight of total number accepted (excluding band)	36,078.5
Number rejected for eccentricity of interior cavity	1	Mean weight of projectile (complete)	*177.6 181.6
Number rejected for defects in material or finish	9	Number bands examined	205
Total number rejected	10	Number of bands rejected for defects in material or finish	2
Total number accepted	203	Total number of bands rejected	2
Weight of heaviest one accepted (complete)	*179 182	Number of bands accepted	203
Weight of lightest one accepted (complete)	*177 179	Weight of total number accepted	507.5
		Mean weight of band	2.5
		Weight of total number of shot and bands accepted	36,584

* Under original contract drawing; after fifty-two shot had been cast the length of "cylindrical portion of body" was increased 0.25, under authority of the Chief of Ordnance U. S. Army, per telegram dated November 26, 1884.

PHYSICAL PROPERTIES.

Specimen.	Density (actual).	Tenacity.				Band metal.
		Prescribed.	Actual.	Allowed variations.	Actual variations.	
Six specimens, one from each lot of castings	7.1959- 7.3332	....	26,344 31,947	....	+1,344 +6,947	95 parts copper. 5 parts spelter.
Average	7.2650	25,000	27,612	−750	+2,612	

REMARKS.—On these fabrications as bases, a revised drawing, inspector's file No. 247, has been constructed. Shipped to United States Proving Ground, Sandy Hook, N. J., January 16, 1885.

I certify that I have carefully inspected the above-noted projectiles, and that they conform to the dimensions prescribed within the variations allowed; and, further, that the terms of the contract as to material and workmanship have been complied with in their manufacture.

R. BIRNIE, JR.,
Lieutenant of Ordnance, Inspector.

Date of inspection December 31, 1884.

Inspection report of 8-inch ogival-headed Hotchkiss projectiles for breech-loading rifles made for the United States Ordnance Department by West Point Foundry Association, at West Point Foundry, under order of the Chief of Ordnance, U. S. Army, dated January 8, 1885.

Subject of measurement.	Prescribed dimensions.	Allowed variations.	
PROJECTILE.	*Inches.*	*Inch.*	*Pounds.*
Length of cylindrical portion of body to band	*7.60	+0.15	....
Length of head	8.902	—0.17	....
Length of base:			
For band	2.048	±0.01	....
In rear of band	0.5		....
In rear of cylindrical portion	0.25	±0.05	....
Total length of projectile	*19.3	±0.19	....
Diameter of base in rear of band	7.95 7.86	±0.01	....
Radius of head	12.0	±0.05	....
Thickness of bottom	2.3	±0.1	....
Length of interior cavity	10.25		....
Thickness of walls at 4.05 inches from base	2.225	±0.1	....
Eccentricity of axis of interior cavity	....	0.1	....
Diameter of screw-plug hole	1.5	±0.01	....
Pitch of thread on screw-plug hole	8 to the inch.		....
Length of thread on fuse (or screw-plug) hole	2.3	±0.1	....
Number of cannelures under band	4.	....	....
Depth of cannelures under band	0.116 to 1.149		....
Width of cannelures	0.225 to 0.52		....
Weight of projectile, including plug and without band	177.5	....	±2.7 —1.8
BAND.			
Length of band	2.048	±0.01	....
Exterior diameter of band	8.15	±0.01	....
Interior diameter of band (maximum)	7.862	±0.01	....
Thickness of band	0.144	±0.01	....
Radius of curve at front	4.075	....	....
Weight of band	2.5	....	....
Weight of band projectile	180	....	+2.7 —1.8

Number of 8-inch Hotchkiss projectiles examined	20
Total number accepted	20
Weight of heaviest one accepted (complete)	182
Weight of lightest one accepted (complete)	180
Weight of total number accepted (excluding band)	3,583

Mean weight of projectile (complete)	181.15
Number of bands examined	20
Number of bands accepted	20
Weight of total number accepted	50
Mean weight of band	2.5
Weight of total number of shot and bands accepted	3,633

* Dimensions authorized by telegram of Chief of Ordnance, U. S. Army, dated November 26, 1884.

PHYSICAL PROPERTIES.

Specimen.	Density (actual).	Tenacity.				Band metal.
		Prescribed.	Actual.	Allowed variations.	Actual variations.	
One	7.2846	25,000	31,416	—750	+6,416	95 parts copper. 5 parts spelter.

REMARKS.—On these fabrications as bases, a revised drawing, inspector's file No. 247, has been constructed. Shipped to United States Proving Ground, Sandy Hook, N. J., January 16, 1885.

I certify that I have carefully inspected the above-noted projectiles, and that they conform to the dimensions prescribed within the variations allowed; and, further, that the terms of the order as to material and workmanship have been complied with in their manufacture.

R. BIRNIE, JR.,
Lieutenant of Ordnance, Inspector.

Date of inspection, January 9, 1885.

The course of inspection pursued with these shot was as follows:

(1) After the castings had been cleaned and chipped they were examined for serious defects and to verify the "length of interior cavity" and the "thickness of bottom." One shot of each lot was taken to the finishing shop as soon as possible after the casting and cut in two across the thinnest portion of the wall. The tenacity specimen was then cut with a hollow boring tool from the base portion opposite to the base of the core. It was sought to have the results of the tests available before finishing work was begun on the castings.

(2) The cast-iron bodies were weighed, gauged, &c., and "rolled" for eccentricity following their finish in the press.

(3) The bands were examined for defects after being faced at the ends and bored.

(4) The shot having been completely assembled the finished dimensions of the exterior of band were verified and the shot were weighed, and the weight of each, to the nearest pound, stamped on the cast-iron body in rear of the band.

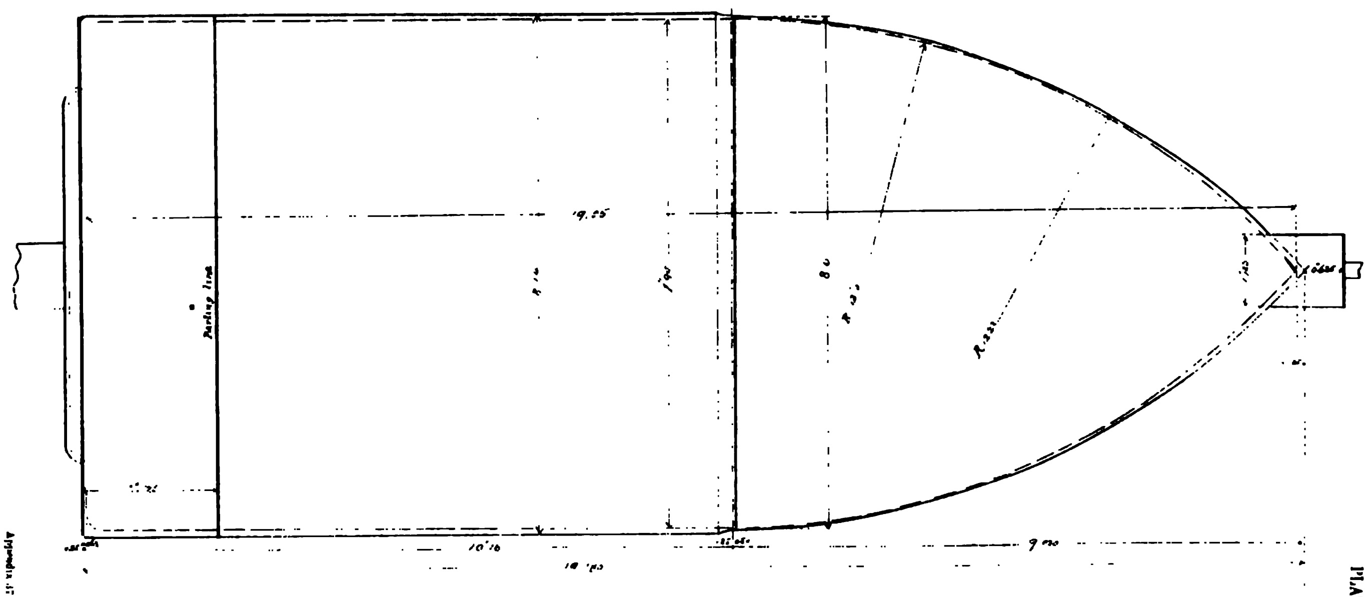
R. BIRNIE, JR.,
Lieutenant of Ordnance.

WEST POINT FOUNDRY, *January* 22, 1885.

PLATE I.

Pattern for 8^in Hotchkiss B.L. Shot.

Showing Shrinkages, Cylinder at Point and
Surplus left on cylindrical portion for finish.



Appendix 37 [illegible]

H Ex1 pt2 v3 49 1

January 13th [illegible]

8 INCH CORED SHOT - WT. 180 LBS.

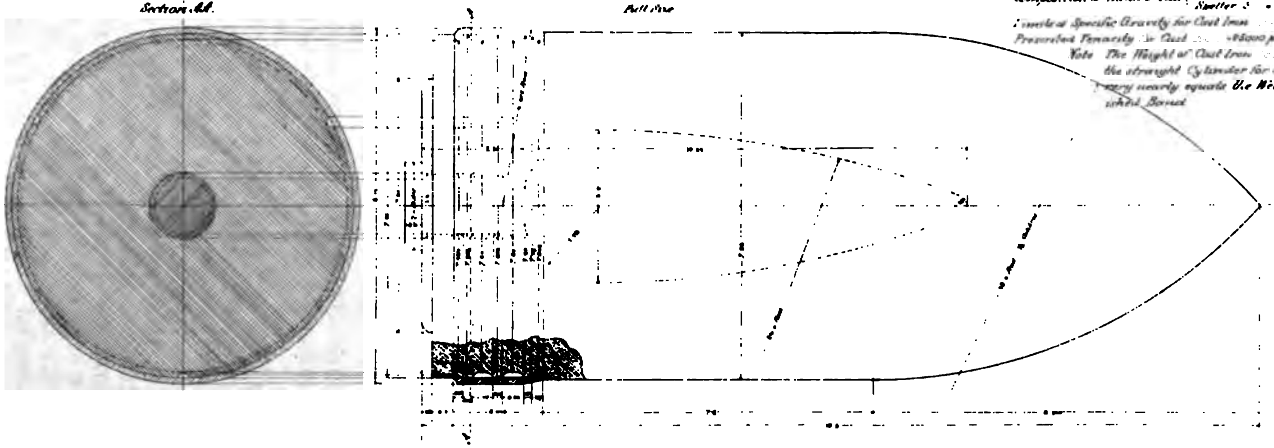
HOTCHKISS PATENT

Full Size

Weight of Cast Iron - 176 pounds
" Base Plug - 1 8 "
" " Band - 2 3 "

Composition of Band Metal { Copper 95 parts
Spelter 5 "

Standard Specific Gravity for Cast Iron [illegible] to 7.30
Prescribed Tenacity for Cast Iron [illegible] 25000 lbs per sq inch
Note The Weight of Cast Iron [illegible] off from the straight Cylinder for fitting Band very nearly equals the Weight of the whole Band



Appendix 17 [illegible]

PLATE II

APPENDIX 38.

T ON THE MANUFACTURE OF 8-INCH CHILLED PROJECTILES.

BY CAPT. D. A. LYLE, ORDNANCE DEPARTMENT.

eneral methods pursued in the manufacture of 8-inch projectiles
n treated before.
bject of "allowed variations" was carefully noted in the fabri-
f this lot of projectiles. It is found that no difficulty is en-
d in holding the contractors to the limits laid down in the pro-
table of allowed variations sent from the Ordnance Office and
ovember 21, 1884.
nall loss of projectiles from erroneous dimensions as compared
ne previous contracts sufficiently demonstrates this fact. I
espectfully recommend that the above mentioned table of
d variations" be adhered to in future contracts for this class of
s. The allowances may be somewhat stringent, but all come
he mechanical possibilities of manufacture by the exercise of
le care. The greatest difficulty seemed to be encountered in
g out of the chilled cast-iron molds for the heads of the pro-
The inspectors recommended the following procedure in this
n:
bore out the chills to their approximate dimensions.
fill them with molten cast iron from one to three times, to ex-
e chill, no attention being paid to the quality of the melted
eat was the only thing required. This treatment expanded the
gave it an initial permanent set, enlarging it.
en, to ream the interior out a little more, but still keeping be-
required diameter.
l again with molten iron and expand the chill as before. This
n should give the chill about all the permanent expansion that
dergo from heat alone.
rse, from oxidation and scaling off, the chill will gradually en-
use. The life of a chill was not definitely determined.
le was found in the thickness of the walls around the largest
of the core cavity. This was discovered to result from the
ry of the core; the convexity on one-half being greater than
her, due to the fact that in molding one-half of the core-box
oved, slightly disturbing and sometimes breaking the surface
re. The upper or defaced half of this core was smoothed and
ce finished by the molder's trowel. The strokes with this in-
were generally directed toward the largest diameter, which
l the convexity of the upper half of the core by carrying the
aterial forward. This resulted in the increase of that semi-
of the core and a consequent reduction in the thickness of the
the projectile on that side.

At the close of the casting two chills were selected for measurement to ascertain the extent of the deformation due to repeated use. The largest and smallest were taken, in order to get the extreme range.

The following exhibits the results of the comparison:

Interior dimensions of cast-iron chill molds.

	Chills.	
	Largest.	Smallest.
	Inches.	*Inches.*
Length of cylinder directly in rear of head	1.	1.
Diameters of cylinder:		
Horizontal	8.185	8.[illegible]
Vertical	8.192	8.[illegible]
Difference	.007	.[illegible]
Diameter at base of ogival head:		
Horizontal	8.083	8.1[illegible]
Vertical	8.098	8.[illegible]
Difference	.015	.[illegible]
Total length interior cavity of chill	10.121	10.1[illegible]

The standard diameter of the cylinder directly in rear of head [illegible] 7″.95, from which it is seen that, provided the metal did not shrink diametrically in cooling, and preserved the dimensions given by the interior of the chill, there would remain .″242 excess of metal to be removed in finishing.

As a matter of fact the metal does contract and less than that amount has to be removed, especially in the earlier castings before the chills become deformed and elliptical.

The shell-hook holes in the ogival head were omitted in this contract and no difficulty was experienced in turning the exterior without their presence, except that the lathes employed were heavier. Defects are sometimes found on the interior of the cavity at the rear end which are difficult to detect.

A shot cast in a previous contract was found to have a crack extending longitudinally from end to end that had eluded the most careful scrutiny, and was only developed when the attempt was made to split it open to discover the depth of chill.

No trouble was experienced in getting the proper depth of chill, as was shown by the sample broken from each lot cast. There were slight variations of course in this depth, but not greater than was to be anticipated.

The major part of the iron used for these projectiles came from chilled car-wheels, which were broken up and melted with a proper proportion of fresh pig.

The junction of the chilled and unchilled parts of these projectiles is weak diametrically, especially with so brittle a material as cast iron. I would therefore recommend that attempts be made to replace these shot with low steel containing enough carbon to take the proper chill and prevent excessive upsetting on impact.

Details of casting.

No. of casting.	Date.	Number cast.	Charge in furnace. Remelted.	Charge in furnace. No. 4 Murkirk.	Charge in furnace. No. 4½ Shaparon.	Charge in furnace. Total.	Tenacity.	Density.	Remarks as to character of chill.
1	Dec. 31	15	4100	1400	300	5800	24923	7. 2563	
2	Jan. 8	18	4000	1400	400	5800	24798	7. 2628	
3	Jan. 12	27	4700	1700	800	6700	26298	7. 2170	
4	Jan. 16	30	5200	1400	....	6600	24546	7. 2197	
5	Jan. 28	28	5200	1800	....	7000	24846	7. 2527	
6	Jan. 29	29	5200	1800	....	7000	25200	7. 2246	
7	Jan. 30	29	4700	1800	400	6900	24481	7. 2193	
8	Jan. 31	30	5300	1400	....	6700	26570	7. 2618	
9	Feb. 2	30	6100	2000	300	8400	25284	7. 2732	
10	Feb. 3	33	6100	1900	400	8400	25279	7. 2696	About right.
11	Feb. 4	34	6100	2000	300	8400	26084	7. 2994	Do.
12	Feb. 5	33	6400	2100	300	8800	27319	7. 2539	Little deep.
13	Feb. 6	38	6600	2200	350	9150	24669	7. 1992	Do.
14	Feb. 7	38	6600	2150	850	9100	26083	7. 2096	About right.
15	Feb. 9	36	6300	2000	200	8500	24704	7. 2827	Little deep.
16	Feb. 10	36	6250	1850	450	8550	24616	7. 2747	Little light.
17	Feb. 11	36	6250	1850	450	8550	25818	7. 2959	About right.
18	Feb. 12	36	6250	1950	450	8650	26175	7. 2851	Little light 1″.
19	Feb. 13	36	6250	1950	450	8650	25111	7. 2791	Do.
20	Feb. 14	38	6450	2050	550	9050	25721	7. 3021	Little deep, but good.
21	Feb. 16	36	6400	2200	450	9050	25465	7. 2898	Good.
22	Feb. 17	36	6300	2200	450	8950	24798	7. 3011	Good, but deep.
23	Feb. 18	36	6300	2200	450	8950	26614	7. 2871	Little deep.
24	Feb. 19	36	6300	2200	450	8950	24351	7. 2750	Good.
25	Feb. 20	38	6450	2050	550	9050	26437	7. 2380	All right.
26	Feb. 21	36	6300	2200	450	8950	24799	7. 2747	Do.
27	Feb. 23	36	6300	2200	450	8950	24636	7. 2833	
28	Feb. 24	38	6600	2200	350	9150	25642	7. 2560	
29	Feb. 25	36	6300	2200	450	8950	26437	7. 2422	
30	Feb. 26	38	6600	2150	350	9100	26702	7. 2725	
31	Feb. 27	36	6300	2100	500	8900	24976	7. 2549	
32	Feb. 28	38	6300	2100	400	8800	25200	7. 2774	

RECAPITULATION.

Number of castings.	Number projectiles cast.	Charge in furnace. Remelted.	Charge in furnace. No. 4 Murkirk.	Charge in furnace. No.—Shaparon.	Charge in furnace. Total.	Tenacity. Maximum.	Tenacity. Minimum.	Tenacity. Mean.	Density. Maximum.	Density. Minimum.	Density. Mean.
		Pounds.	*Pounds.*	*Pounds.*	*Pounds.*						
32	1, 070	190, 500	62, 700	11, 250	264, 450	27319	24351	25455	7. 3021	7. 1992	7. 2622

	Pounds.
Total weight of iron melted	264, 450
Total weight of shot	182, 435

Table showing weights of 1,000 8-*inch Butler chilled shot.*

Number weighing— 179 pounds.	180 pounds.	181 pounds.	182 pounds.	183 pounds.	184 pounds.	185 pounds.	Total.	Remarks.
1	37	157	298	353	146	8	1, 000	Mean weight, 182.4 pounds.

Inspection report of 10 8-inch ogival-headed Butler chilled shot for 8-inch muzzle loading rifles, made for the U. S. Ordnance Department by South Boston Iron Works, at South Boston Foundry, under order of Chief of Ordnance, U. S. A., dated April 3, 1885.

Subject of measurement.	Prescribed dimensions.	Allowed variations.	
PROJECTILE.	*Inches.*	*Inches.*	*Per ct.*
Length of cylindrical portion of body	7.3 1.05	.... +2 −1	+1½ ....
Length of head	8.95		−2
Length of base for sabot	2	±.05	....
Total length of projectile	19.30	....	±1
Diameter of cylindrical portion	7.95 7.80	±.01 ±.025	....
Diameter of base over lock	6.375	....	....
Radius of head	12	±.05	....
Thickness of bottom	2.25	±.1	....
Length of interior cavity	10.8	±.1	....
Thickness of walls at 3.8 inches from base	2.35	....	....
Eccentricity of axis of interior cavity	0	±.1	....
Diameter of screw-plug hole	1.5	±.01	....
Pitch of thread on screw-plug hole	8	....	....
Length of thread on screw-plug hole	2.325	....	....
SABOT.			
Height of sabot	1.7	±.01	....
Exterior diameter of sabot	7.95	±.01	....
Interior diameter of sabot { projection	5.875	±.01	....
Interior diameter of sabot { recess	6.375	±.01	....
Maximum thickness of outer lip	0.23	±.01	....
Minimum thickness of outer lip	0.23	±.01	....
Depth of cannelure	0.8	±.01	....
	Pounds.		
Weight of sabot and projectile	183	....	±2

Number of 8-inch Butler chilled shot examined	10
Total number accepted	10
Weight of heaviest one accepted	183
Weight of lightest one accepted	180
Weight of total number accepted	1,816
Mean weight of projectile, pounds	181.6

Number of sabots examined	10
Number of sabots accepted	10
Weight of total number accepted (rough state) pounds	[illegible]
Mean weight of sabot .... pounds	[illegible]
Weight of total number of shot and sabots accepted .... pounds	[illegible]

PHYSICAL PROPERTIES.

Specimen	Density (actual.)	Tenacity.		
		Prescribed.	Actual.	Allowed variations.
				Per cent.
Mean	7.2622	25000	25455	−3
Maximum	7.3021	....	27319	....
Minimum	7.1992	24250	24351	....

REMARKS.—Shipped to Watertown Arsenal, April 6, 1885.

I certify that I have carefully inspected the above-noted projectiles, and that they conform to the dimensions prescribed within the variations allowed; and further, that the terms of the order as to material and workmanship have been complied with in their manufacture.

Date of inspection, April 6, 1885.

D. A. LYLE,
Captain of Ordnance, Inspector.

Inspection report of 1,000 8-*inch ogival-headed Butler chilled shot for* 8-*inch muzzle-loading rifles, made for the U. S. Ordnance Department by South Boston Iron Works, at South Boston Foundry, under contract of Chief of Ordnance, U. S. Army, dated December* 1, 1884.

Subject of measurement.	Prescribed dimensions.	Allowed variations.	
PROJECTILE.	*Inches.*	*Inch.*	*P. ct.*
Length of cylindrical portion of body	7.3 1.05	+.2 −.1	+1½
Length of head	8.95	....	−2
Length of base for sabot	2	±.05	....
Total length of projectile	19.30	....	±1
Diameter of cylindrical portion	7.95 7.80	±.01 ±.025	....
Diameter of base over lock	6.375	....	....
Radius of head	12	±.05	....
Thickness of bottom	2.25	±.1	....
Length of interior cavity	10.3	±.1	....
Thickness of walls at 3.8 inches from base	2.35	....	....
Eccentricity of axis of interior cavity	....	±.1	....
Diameter of screw-plug hole	1.5	±.01	....
Pitch of thread on screw-plug hole	8.	....	....
Length of thread on screw-plug hole	2.325	....	....
SABOT.			
Height of sabot	1.7	±.01	....
Exterior diameter of sabot	7.95	±.01	....
Interior diameter of sabot { projection	5.875	±.01	....
Interior diameter of sabot { recess	6.375	±.01	....
Maximum thickness of outer lip	.23	±.01	....
Minimum thickness of outer lip	.23	±.01	....
Depth of cannelure	.8	±.01	....
	Pounds.		
Weight of sabot and projectile	183	....	±2

Number of 8-inch Butler chilled shot examined	1,060
Number rejected for erroneous dimensions of cylindric body or base	6
Number rejected for erroneous dimensions of interior cavity	1
Number rejected for eccentricity of interior cavity	28
Number rejected for defects in material or finish	25
Total number rejected	60*
Total number accepted	1,000
Weight of heaviest one accepted.....lbs..	185
Weight of lightest one accepted......do..	179

Weight of total number accepted..lbs..	182,435
Mean weight of projectile..........do..	182.4
Number of sabots examined	1,002
Number of sabots rejected for erroneous dimensions	0
Number of sabots rejected for defects in material or finish	2
Total number of sabots rejected	2
Number of sabots accepted	1,000
Weight of total number accepted (rough state)..........lbs..	10,437½
Mean weight of sabot..........do..	10 7/16
Weight of total number of shot and sabots accepted..........lbs..	182,435

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* Sixty-two were provisionally rejected for erroneous dimensions, but were subsequently accepted having been "machined" so as to bring them within the requirements of the contract.

PHYSICAL PROPERTIES.

Specimen.	Density (actual).	Tenacity.		
		Prescribed.	Actual.	Allowed variations.
				Per cent.
Mean	7.2622	25,000	25,455	−3
Maximum	7.3021	....	27,319	....
Minimum	7.1992	24,250	24,351	....

REMARKS.—Shipped to Watertown Arsenal, March 28, 1885.

I certify that I have carefully inspected the above noted projectiles, and that they conform to the dimensions prescribed within the variations allowed; and, further, that the terms of the contract as to material and workmanship have been complied with in their manufacture.

Date of inspection, March 20, 1885.

D. A. LYTLE,
Captain of Ordnance, Inspector.

APPENDIX 39.

INSPECTION REPORT OF 12-INCH EUREKA MORTAR SHELL AND SABOTS

BY LIEUT. ROGERS BIRNIE, JR., ORDNANCE DEPARTMENT.

MAY 25, 1885.

GENERAL: I have the honor to transmit herewith inspection reports of the usual form for the following lots of 12-inch Eureka shell and sabots for 12-inch muzzle-loading rifled mortar, which have been recently completed at this foundry, viz:

(1) Fifteen 580-pound shell, complete, delivered November 6, 1884.
(2) Seventy-eight 610-pound shell, complete, delivered April 29, 1885.
(3) Twenty-five 610 pound shell, complete, delivered April 13, 1885.
(4) Ninety-eight 610 pound shell, complete, delivered April 29, 1885.
(5) Ninety-two 585-pound shell, complete, delivered May 4, 1885.
(6) Two hundred sabots, delivered May 7, 1885.

These projectiles being intended for experimental firing, the contract provided for modifications in dimensions and material contingent upon the results derived from firing a limited number of the first made.

The cast-iron bodies of the heavier shell (610-pound) were, however, as authorized by the contract, completed in advance of the firing test.

The fifteen 580-pound shell were completed first for the firing test; they were made after the dimensions of drawing attached to contract. The completed shells were found to average 7.5 pounds under weight, and as a result of the firing it was decided to increase the thickness of sabot through the portion of base around plug from 0.3 to 0.4 inch; the sabot otherwise remained unchanged, but increased dimensions were prescribed for the shell body, and the weight of projectile complete was fixed at 585 pounds. Plate I gives the final drawing for these shells, which was followed in making the ninety-five 585-pound shell named above (item 5). The average weight of these shell is 588.6 pounds. To reduce the weight to 585 pounds the cylindrical portion of the body of shell, which has a diameter of 11.92 inches, should be changed from 13.4 to 13.275 inches; and to reduce the weight to 580 pounds this dimension should be made 13.1 inches, with a corresponding decrease of the total length of shell body in each case, the dimensions otherwise to remain unchanged.* The core capacity of this shell is 857 cubic inches, calculated to contain a bursting charge of 30 pounds of powder upon a basis of 0.035 pound per cubic inch of space.

After casting a number of the 610-pound shell bodies (seventy-eight, item 2), the length of cylindrical portion of body was increased from 11.9 to 12.176 inches, and the total length of shell was correspondingly increased. Plate II, Fig. 1, shows the drawing used for dimensions of the one hundred and twenty-three shell bodies included in items 3 and 4 above. The sabots placed upon the lot of ninety-eight were the same as those shown in Plate I. The sabots placed upon the lot of twenty-five were altered for special experiments in firing. A drawing of these altered sabots is shown, Fig. 2, Plate II. Even with the increased length these shell fall some 6 pounds under the prescribed weight of 610 pounds for the shell complete. In order to make them of full weight the length of cylindrical portion of body at rear should be increased to 12.4 inches, and the total length of projectile should be made 34.0 inches.

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* If the dimensions of core remain unchanged, a change of 0.1 inch in length of cylindrical portion of shell body will effect a change of 2.9 pounds (nearly) in the weight.

The following tables give the charges of iron used for the castings and the results of tests of the metal of the shell:

Record of castings and tests of 580 *and* 585 *pound* 12-*inch mortar shell* (*Eureka.*)

[All castings made direct from air-furnace, using a small ladle with capacity for two castings. Shell cast base up, and each "fed" and "stirred" through two "risers" at opposite sides of the core stem. Tenacity specimen tested from 2-inch proof-bar and from one specimen shell for each lot of castings. Specimen shell cut in two near base of core and specimen bored out from wall. For castings made October 21 and 23, 1884, the cylindrical portion of original shell pattern was reduced to three-sixteenths inch surplus for finishing, causing the reduction in rough weight. For castings made April 6 1885, and subsequently, a new pattern was used to make the weight of finished projectile equal 585 pounds and suit the new dimensions of projectile as prescribed by drawing dated April 4, 1885 (see Plate I).]

Date.	Number cast.	Average weight in rough state.	Charge of iron in percentages.									Physical quantities.			
												From proof bar.		From specimen shot.	
			Gere No. 2.	Gere No. 3.	Hudson No. 1.	Air-furnace scrap.	Cupola scrap.	Gun scrap.	Old welding-pots.	Old shot.	Anvil block.	Tenacity.	Specific gravity.	Tenacity.	Specific gravity.
1884.															
Oct. 3	10	577.0	17.6	17.6	4.7	17.6	.....	.....	42.2	.....	.....	23,317	7.3147	26,047	7.2498
21	4	563.2	17.7	17.7	....	17.7	.....	.....	46.8	.....	.....	26,653	7.2538	28,264	7.1686
23	1	566.0	.....	32.6	....	18.9	.....	.....	48.3	.....	.....	27,966	7.2743	29,711	7.2293
1885.															
Apr. 6	20	583.8	26.8	.....	24.6	31.9	.....	16.6	.....	.....	.....	30,138	7.3026	31,375	7.2768
8	19	584.3	14.4	.....	24.4	50.0	.....	.....	.....	.....	11.4	27,958	7.2494	32,474	7.2590
10	20	583.3	22.6	.....	20.0	19.3	22.6	15.3	.....	.....	.....	31,649	7.2629	31,039	7.2012
13	20	586.3	26.6	.....	16.6	20.0	.....	.....	.....	14.6	22.2	29,952	7.3250	33,909	7.2401
15	16	585.3	26.6	.....	16.6	20.0	.....	.....	.....	14.6	22.2	30,159	7.3194	30,518	7.1881

SUMMARY.

Castings	**110**
Defective castings	**1**
Shell bodies finished	**109**
Shell bodies rejected after finishing	**2**
Total number of shell bodies accepted	**107**

Weights.		**Original contract drawing.**	**Drawing dated April 4, 1885.**
Heaviest shell body finished	**pounds**	**546**	**566**
Lightest shell body finished	**do**	**542**	**557**
Average shell body finished	**do**	**544.5**	**561.5**
Average specific gravity		**7.2159**	**7.2315**

Record of castings and tests of 610 *pound* 12 *inch mortar shell* (*Eureka*).

[All castings made direct from air-furnace, using a small ladle with capacity for two castings. Shell cast base up, and each "fed" and "stirred" through two "risers" at opposite sides of the core stem. Tenacity specimen tested from 2-inch proof-bar and from one specimen shell for each lot of castings. Specimen shell cut in two near base of core and specimen bored out from wall. Between the dates October 9 and 14 the cylindrical portion of shell pattern was reduced to three-sixteenths inch surplus for finishing, causing the reduction in rough weight. For castings made October 21 and subsequently, the shell pattern was increased 0.3 inch in length to correspond to new dimensions of drawing (see Fig. 1, Plate II).]

Date.	Number cast.	Average weight in rough state.	Charge of iron in percentages.								Physical qualities.			
			Gere No. 2.	Gere No. 3.	Hudson No. 1.	Hudson No. 2 (extra).	Air-furnace scrap.	Gun scrap.	Old welding-pots.	Shell and shot.	From proof bar.		From specimen shot.	
											Tenacity.	Specific gravity.	Tenacity.	Specific gravity.
1884.														
Oct. 7	20	602.6	33.3	3.7	14.8	.....	18.5	......	20.6	.....	29,088	7.1941	27,643	7.0835
9	20	600.2	59.0	......	11.5	.....	12.9	......	16.5	.....	27,246	7.1589	30,205	7.1301
14	20	586.7	32.2	7.1	14.2	.....	17.8	......	28.5	.....	29,582	7.2022	28,227	7.1286
15	20	585.0	33.3	11.1	.....	.....	18.5	......	37.0	.....	26,837	7.1833	30,582	7.1178
21	16	590.3	17.7	17.7	.....	.....	17.7	......	46.8	.....	26,653	7.2538	28,264	7.1086
23	19	593.4	......	32.6	.....	.....	18.9	......	48.3	.....	27,966	7.2743	29,711	7.2293
25	19	598.5	3.2	17.4	.....	.....	10.3	5.8	47.7	15.4	27,689	7.3150	28,502	7.1910
28	20	590.7	25.5	4.8	.....	.....	24.8	......	44.8	.....	24,247	7.2019	26,436	7.1199
Nov. 30	20	593.5	26.7	......	....	.....	12.7	5.1	45.8	9.5	22,216	7.2645	29,343	7.1882
1	18	599.5	30.9	......	....	.....	12.9	17.3	38.7	...	25,943	7.3043	30,467	7.2357
5	12	598.2	23.5	......	....	.....	22.3	20.9	33.1	....	24,114	7.3620	28,394	7.3273
25	4	602.5	......	......	....	28.5	33.1	......	18.5	19.8	30,264	7.3278	28,854	7.2100

SUMMARY.

Castings	[illegible]
Defective castings	**2**
Cut up for additional tests	**1**
Shell bodies finished	**205**
Shell bodies rejected after finishing	**4**
Total number of shell bodies accepted	**201**

Weights.		Original pattern.	Enlarged pattern.
Heaviest shell body finished	pounds..	568	584
Lightest shell body finished	do....	560	570
Average shell body finished	do....	562.9	576.5
Average specific gravity		7.1156	7.2022

instance specimens for tenacity were taken from four different parts of the same shell casting, with the following results:

	Pounds tenacity.
Point of shell (on axial line)	20, 860
Side of head (normal to curve)	22, 225
Wall (at side of core)	24, 028
Base of shell (parallel to axis)	26, 047

In another case the specimen from the extreme point gave 22,134 pounds, and that from the wall of the same shell 24,195 pounds tenacity.* The metal will generally be found densest at the point (shell cast base up), but it is probable that in the cooling process the crystallization of the metal there is not so disposed as to give the best results for tests, at least as regards a tensile test.

SABOTS.

The two hundred extra sabots supplied were made after the drawing given (Plate I). An iron pattern was made for casting. All the sabots and the castings were made in green sand. After casting, each sabot was pressed into shape by hydraulic pressure over a templet made as a counterpart of the conical base of shell. This put them in good condition for mounting in the lathe, where they were again placed upon a "chuck" or form identical with the base portion of shell, whereon they could be entirely finished without dismounting, since the interior of the sabot requires no machine finish. The final inspection brought out the difficulty of making these castings perfectly sound. The principal cause of rejection arose from a "draw" beneath the surface in the thick portion of the base where it joins the rim of the sabot. Where this draw was of considerable extent the cutting of the groove showed cavities in the metal at the bottom of the groove.

The following gives a record of the castings:

Record of castings, Eureka sabots, for 12-inch muzzle-loading rifled mortar shell.

Castings.			Metals used.						
Date.	Number cast.	Average rough weight of sabot.	Copper (Quincy).	Brass (remelted).	Spelter (Bergenport.)	Total weight.	Per cent. of spelter.	Surplus metal recovered.	Loss of metal.
1884.		*Pounds.*	*Pounds.*	*Pounds.*	*Pounds.*	*Pounds.*		*Pounds.*	*Pounds.*
Oct. 2	4	25. 75	105	10	35	150	25. 00	45	2
3	8	25. 81	140	65	47	252	25. 13	41	4. 5
20	5	26. 8	73	100	24	197	24. 74	57	6
1885.									
Apr. 3	4	27. 5	75	35	25	135	25. 00	21	4
4	12	27. 5	228	80	77	385	25. 24	48	7
6	14	27. 5	270	60	90	420	25. 00	26	9
7	15	27. 5	232	150	78	460	25. 16	35	12. 5
8	15	27. 5	240	150	80	470	25. 00	45. 5	12
11	15	27. 5	342	30	114	486	25. 00	62	11. 5
13	28	27. 5	735	50	245	1, 030	25. 00	235	25
14	27	27. 5	531	200	177	908	25. 00	145	20. 5
15	14	27. 5	240	100	80	420	25. 00	26	9
16	30	27. 5	700	65	235	1, 000	25. 13	153	22
17	30	27. 5	750	40	250	1, 040	25. 00	192	23
18	24	27. 5	507	100	169	776	25. 00	100	16
20	15	27. 5	280	130	94	504	25. 13	77	14. 5
21	15	27. 5	280	135	94	509	25. 13	82	14. 5
22	30	27. 5	663	120	221	1, 004	25. 00	154	25
23	28	27. 5	660	125	220	1 005	25. 00	211	24
24	30	27. 5	575	250	192	1, 017	25. 03	166	26
25	30	27. 5	570	245	190	1, 005	25. 00	154	26
28	30	27. 5	570	245	190	1, 005	25. 00	154	26
29	30	27. 5	570	245	190	1, 005	25. 00	154	26
30	30	27. 5	570	245	190	1, 005	25. 00	154	26
May 1	30	27. 5	570	250	190	1, 010	25. 00	155	30
2	30	27. 5	570	250	190	1, 010	25. 00	155	30
5	7	27. 5	....	240	....	240	25. 00	39	8

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* This test, showing a tenacity below the prescribed limit of 25,000 pounds, was not acceptable; it is given only as an instance of the relative strength of the two specimens taken.

Record of castings and tests of 610 *pound* 12 *inch mortar shell* (*Eureka*).

[All castings made direct from air-furnace, using a small ladle with capacity for two castings. Shell cast base up, and each "fed" and "stirred" through two "risers" at opposite sides of the core stem. Tenacity specimen tested from 2-inch proof-bar and from one specimen shell for each lot of castings. Specimen shell cut in two near base of core and specimen bored out from wall. Between the dates October 9 and 14 the cylindrical portion of shell pattern was reduced to three-sixteenths inch surplus for finishing, causing the reduction in rough weight. For castings made October 21 and subsequently, the shell pattern was increased 0.3 inch in length to correspond to new dimensions of drawing (see Fig. 1, Plate II).]

Date.	Number cast.	Average weight in rough state.	Charge of iron in percentages.								Physical qualities.			
			Gere No. 2.	Gere No. 3.	Hudson No. 1.	Hudson No. 2 (extra).	Air-furnace scrap.	Gun scrap.	Old welding-pots.	Shell and shot.	From proof bar.		From specimen shot.	
											Tenacity.	Specific gravity.	Tenacity.	Specific gravity.
1884.														
Oct. 7	20	602.6	33.3	3.7	14.8	.....	18.5	......	29.6	.....	29,088	7.1941	27,043	7.[illegible]
9	20	600.2	59.0	......	11.5	.....	12.9	......	16.5	.....	27,246	7.1589	30,205	7.[illegible]
14	20	586.7	32.2	7.1	14.2	.....	17.8	......	28.5	.....	29,582	7.2022	28,227	7.[illegible]
15	20	585.0	33.3	11.1	.....	.....	18.5	......	37.0	.....	26,837	7.1833	30,582	7.[illegible]
21	16	590.3	17.7	17.7	.....	.....	17.7	......	46.8	....	26,653	7.2538	28,264	7.[illegible]
23	19	593.4	......	32.6	.....	.....	18.9	......	48.3	.....	27,966	7.2743	29,711	7.[illegible]
25	19	598.5	3.2	17.4	.....	.....	10.3	5.8	47.7	15.4	27,689	7.3150	28,502	7.[illegible]
28	20	590.7	25.5	4.8	.....	.....	24.8	......	44.8	....	24,247	7.2019	26,436	7.[illegible]
Nov. 30	20	593.5	26.7	......	....	.....	12.7	5.1	45.8	9.5	22,216	7.2645	29,343	7.[illegible]
1	18	599.5	30.9	......	....	.....	12.9	17.3	38.7	...	25,043	7.3043	30,467	7.[illegible]
5	12	598.2	23.5	......	....	.....	22.3	20.9	33.1	....	24,114	7.3620	28,394	7.[illegible]
25	4	602.5	......	......	....	28.5	33.1	......	18.5	19.8	30,264	7.3278	28,854	7.[illegible]

SUMMARY.

Castings	208
Defective castings	2
Cut up for additional tests	1
Shell bodies finished	205
Shell bodies rejected after finishing	4
Total number of shell bodies accepted	201

Weights.	Original pattern.	Enlarged pattern.
Heaviest shell body finished ... pounds	568	586
Lightest shell body finished ... do	560	570
Average shell body finished ... do	562.9	578.5
Average specific gravity	7.1156	7.2[illegible]

It was found necessary to "feed" the casting through two risers in the base, symmetrically disposed with reference to the core, since feeding on one side alone caused a deflection of the core and rendered the shell eccentric. The tenacity specimen tested from the proof-bar cast with each lot was used for the information of the founders. This test cannot be relied upon to give a correct test of the strength of the metal in the castings proper. The metal of the proof-bar will generally be found more dense than that of the shell, and, on an average, will give some 2,000 pounds per square inch less tenacity than that of the shell. In exceptional cases the tenacity of the proof-bar specimen will be the greater, particularly in the case where the iron of the casting has a natural tendency to softness. The quicker cooling of the proof-bar tends to prevent crystallization, and the metal of the bar will nearly always be harder and closer grained than that of the casting, so if the iron is naturally high the metal of the bar loses strength, owing to its excessive hardness.

The position of the test specimen in the shell has an influence upon the tenacity, which also varies for different natures of iron. The position selected for the test specimen taken from the shell—the wall of shell—gives probably a just result for the average tenacity. In one instance specimens for tenacity were taken from four different parts of the same shell casting, with the following results:

	Pounds tenacity.
Point of shell (on axial line)	20,860
Side of head (normal to curve)	22,225
Wall (at side of core)	24,028
Base of shell (parallel to axis)	26,047

In another case the specimen from the extreme point gave 22,134 pounds, and that from the wall of the same shell 24,195 pounds tenacity.* The metal will generally be found densest at the point (shell cast base up), but it is probable that in the cooling process the crystallization of the metal there is not so disposed as to give the best results for tests, at least as regards a tensile test.

SABOTS.

The two hundred extra sabots supplied were made after the drawing given (Plate I). An iron pattern was made for casting. All the sabots and the castings were made in green sand. After casting, each sabot was pressed into shape by hydraulic pressure over a templet made as a counterpart of the conical base of shell. This put them in good condition for mounting in the lathe, where they were again placed upon a "chuck" or form identical with the base portion of shell, whereon they could be entirely finished without dismounting, since the interior of the sabot requires no machine finish. The final inspection brought out the difficulty of making these castings perfectly sound. The principal cause of rejection arose from a "draw" beneath the surface in the thick portion of the base where it joins the rim of the sabot. Where this draw was of considerable extent the cutting of the groove showed cavities in the metal at the bottom of the groove.

The following gives a record of the castings:

Record of castings, Eureka sabots, for 12-inch muzzle-loading rifled mortar shell.

Castings.			Metals used.						
Date.	Number cast.	Average rough weight of sabot.	Copper (Quincy).	Brass (remelted).	Spelter (Bergenport.)	Total weight.	Per cent. of spelter.	Surplus metal recovered.	Loss of metal.
1884.		*Pounds.*	*Pounds.*	*Pounds.*	*Pounds.*	*Pounds.*		*Pounds.*	*Pounds.*
Oct. 2	4	25.75	105	10	35	150	25.00	45	2
3	8	25.81	140	65	47	252	25.13	41	4.5
20	5	26.8	73	100	24	197	24.74	57	6
1885.									
Apr. 3	4	27.5	75	35	25	135	25.00	21	4
4	12	27.5	228	80	77	385	25.24	48	7
6	14	27.5	270	60	90	420	25.00	26	9
7	15	27.5	232	150	78	460	25.16	35	12.5
8	15	27.5	240	150	80	470	25.00	45.5	12
11	15	27.5	342	30	114	486	25.00	62	11.5
13	28	27.5	735	50	245	1,030	25.00	235	25
14	27	27.5	531	200	177	908	25.00	145	20.5
15	14	27.5	240	100	80	420	25.00	26	9
16	30	27.5	700	65	235	1,000	25.13	153	22
17	30	27.5	750	40	250	1,040	25.00	192	23
18	24	27.5	507	100	169	776	25.00	100	16
20	15	27.5	280	130	94	504	25.13	77	14.5
21	15	27.5	280	135	94	509	25.13	82	14.5
22	30	27.5	663	120	221	1,004	25.00	154	25
23	28	27.5	660	125	220	1 005	25.00	211	24
24	30	27.5	575	250	192	1,017	25.03	166	26
25	30	27.5	570	245	190	1,005	25.00	154	26
28	30	27.5	570	245	190	1,005	25.00	154	26
29	30	27.5	570	245	190	1,005	25.00	154	26
30	30	27.5	570	245	190	1,005	25.00	154	26
May 1	30	27.5	570	250	190	1,010	25.00	155	30
2	30	27.5	570	250	190	1,010	25.00	155	30
5	7	27.5	....	240	....	240	25.00	39	8

---

* This test, showing a tenacity below the prescribed limit of 25,000 pounds, was not acceptable; it is given only as an instance of the relative strength of the two specimens taken.

SUMMARY.

Total number of sabots cast	[illegible]
Not examined	[illegible]
Rough castings rejected for defects or erroneous dimensions	[illegible]
Finished sabots rejected for defects of material	17
Total number of finished sabots accepted	[illegible]

Inspection report of 585-pound 12-inch ogival-headed Eureka shell, for muzzle-load rifled mortar, made for the United States Ordnance Department by West Point Foun Association, at West Point Foundry, under contract of Chief of Ordnance, U. S. Arm dated August 7, 1884.

Subject of measurement.	Prescribed dimensions.	Allowed variations.	
PROJECTILE.	*Inches.*	*Inch.*	*Per ct.*
Length of cylindrical portion of body { rear	13.4	....	+2
Length of cylindrical portion of body { front	2.6	....	
Length of conical portion of body	1.25	....	
Length of head	13.4	....	−2
Length of base for sabot	2.6	±0.05	....
Total length of projectile	35.0	....	±1
Diameter of cylindrical portion { rear	11.92	±0.01	....
Diameter of cylindrical portion { front	11.97		....
Diameter of conical base under sabot { rear	11.32	±0.01	....
Diameter of conical base under sabot { front	11.72		....
Radius of head	18.0	±0.05	....
Thickness of bottom	3.0	±0.1	....
Length of interior cavity	24.0	±0.1	....
Thickness of walls at 5.9 inches from base	2.2	....	....
Thickness of walls at 17.5 inches from base	2.225	....	....
Eccentricity of axis of interior cavity..per cent. of caliber	....	....	1½
Diameter of fuze (and screw-plug) holes at bottom of thread	1.125 2.6	....	....
Pitch of thread on fuze (and screw-plug) holes. to the inch	12 6	....	....
Length of thread on fuze (and screw-plug) holes	1.0 3.0	....	....
	Pounds.		
Weight of projectile with plug	561	....	....
SABOT.	*Inches.*		
Radius for outside cup of base	3.15	±0.01	....
Radius for inside cup of base	6.3		
Height of sabot	3.75		
Exterior diameter of sabot	11.97		
Thickness of base around plug	0.4		
Thickness of parallel portion of base	0.25		
Distance of cannelure from rear	0.8		
Depth of cannelure	0.35		
Maximum width of cannelure	0.3		
	Pounds.		
Weight of sabot (computed)	24	....	....
Weight of sabot and projectile	585	+8.8 −4.0	....

Number of 585-pound 12-inch Eureka shell examined	95
Number rejected for defects in material or finish	3
Total number rejected	3
Total number accepted	92
Weight of heaviest one accepted (including sabot) lbs.	593
Weight of lightest one accepted (including sabot) lbs.	584
Weight of total number accepted (including sabot)	52,135.2
Mean weight of projectile (including sabot) lbs.	588.58

Number of sabots examined	[illegible]
Number of sabots rejected for erroneous dimensions (rough castings)	7
Number of sabots rejected for defects in material or finish	1
Total number of sabots rejected	8
Number of sabots accepted	[illegible]
Weight of total number accepted. lbs.	[illegible]
Mean weight of sabot do.	[illegible]
Weight of total number of shot and sabots accepted lbs.	[illegible]
Actual weight of base plug (average equal) lbs.	[illegible]

PHYSICAL PROPERTIES.

Specimen.	Density (actual).	Tenacity.				Sabot metal.
		Prescribed.	Actual.	Allowed variations.	Actual variations.	
Five specimens....	From 7.1881 To 7.2768	25,000	From 30,518 To 33,909	—0	From +5,518 To +8,909	Copper, 75 parts. Zinc, 25 parts.
Average......	7.2315	....	31,903	....	+6,903	

Seven projectiles in addition to the 85 required to complete contract accepted under authority from e Chief of Ordnance, U. S. Army, dated April 30, 1885

REMARKS.—Shell and sabots made after drawing dated April 4, 1885, shipped to United States oving ground, Sandy Hook, N. J., May 16, 1885.

I certify that I have carefully inspected the above-noted projectiles, and that they conform to the mensions prescribed within the variations allowed; and, further, that the terms of the contract as to aterial and workmanship have been complied with in their manufacture.

MAY 4, 1885.

R. BIRNIE, JR.,
Lieutenant of Ordnance, Inspector.

spection report of 580*-pound* 12*-inch ogival-headed Eureka shell for muzzle-loading rifled mortar, made for the United States Ordnance Department by West Point Foundry Association, at West Point Foundry, under contract of Chief of Ordnance, U. S. Army, dated August* 7, 1884.

Subject of measurement.	Prescribed dimensions.	Allowed variations.	
PROJECTILE.			
	Inches.	*Inch.*	*Per ct.*
Length of cylindrical portion of body, rear	11.9	....	+2
Length of cylindrical portion of body, front	2.6	....	
Length of conical portion of body	1.25	....	
Length of head	13.4	....	−2
Length of base for sabot	2.6	±.05	....
Total length of projectile	33.5	....	±1
Diameter of cylindrical portion, rear	11.92	±.01	....
Diameter of cylindrical portion, front	11.97		
Diameter of conical base under sabot, rear	11.32	±.01	....
Diameter of conical base under sabot, front	11.72		
Radius of head	18.0	±.05	....
Thickness of bottom	3.0	±.01	....
Length of interior cavity	22.45	±.01	....
Thickness of walls at 5.9 inches from base	2.25	....	....
Thickness of walls at 15.8 inches from base	2.275	....	....
Eccentricity of axis of interior cavity..per cent. of caliber..	....	....	1¼
Diameter of screw-plug hole	2.6	±.01	....
Pitch of thread on screw-plug hole............to the inch..	6	....	....
Length of thread on screw-plug hole	3.0	....	....
	Pounds.		
Weight of projectile with plug	556	....	....
SABOT.			
	Inches.		
Radius for outside cup of base	3.15	±.01	....
Radius for inside cup of base	6.3		
Height of sabot	3.75		
Exterior diameter of sabot	11.97		
Thickness of base around plug	.3		
Thickness of parallel portion of base	.25		
Distance of cannelure from rear	.8		
Depth of cannelure	.35		
Maximum width of cannelure	.3		
	Pounds.		
Weight of sabot (computed)	24	....	....
Weight of sabot and projectile	580	+8.7 −5.8	....

umber of 580 pound 12-inch Eureka shell examined	15
tal number accepted	15
eight of heaviest one accepted (including sabot)..........lbs..	576
eight of lightest one accepted (including sabot)..........lbs..	570
eight of total number accepted (excluding sabot)..........lbs..	8,276.45
Mean weight of projectile (including sabot)..........lbs..	572.53
Number of sabots examined	15
Number of sabots accepted	15
Weight of total number accepted..lbs..	311.75
Mean weight of sabot	20.78
Weight of total number of shot and sabots accepted..........lbs..	8,588.2
Actual weight of base plug (av'ge)..do..	6.4

PHYSICAL PROPERTIES.

Specimen.	Density (actual).	Tenacity.				Sabot metal.
		Prescribed.	Actual.	Allowed variations.	Actual variations.	
Three specimens...	From 7.1686 To 7.2498	25,000	From 26,047 To 29,711	−0	From +1,047 To +4,711	Copper, 75 parts. Zinc, 25 parts.
Average.....	7.2159	....	28,007	....	+3,007	

REMARKS.—Projectiles and sabots made after original contract drawing (dated June 10, [illegible] Shipped to United States proving-ground, Sandy Hook, New Jersey, ten on October 21, and [illegible] November 8, 1884.

I certify that I have carefully inspected the above-noted projectiles, and that they conform to the dimensions prescribed within the variations allowed; and, further, that the terms of the contract as to material and workmanship have been complied with in their manufacture.

Date of inspection, October 17 and November 6, 1884.

R. BIRNIE, JR.,
Lieutenant of Ordnance, Inspector.

Inspection report of 610-*pound* 12-*inch ogival-headed Eureka shell for muzzle-loading rifled mortar, made for the United States Ordnance Department by West Point Foundry Association, at West Point Foundry, under contract of Chief of Ordnance, U. S. Army, dated August* 7, 1884.

Subject of measurement.	Prescribed dimensions.	Allowed variations.	
		Inch.	*Per ct.*
PROJECTILE.	*Inches.*		
Length of cylindrical portion of body, rear	11.9	....	+2
Length of cylindrical portion of body, front	2.6	....	
Length of conical portion of body	1.25	....	....
Length of head	13.4	....	−2
Length of base for sabot	2.6	±.05	....
Total length of projectile	33.5	....	±1
Diameter of cylindrical portion, rear	11.92	±.01	....
Diameter of cylindrical portion, front	11.97		
Diameter of conical base under sabot, rear	11.32	±.01	....
Diameter of conical base under sabot, front	11.72		
Radius of head	18.0	±.05	....
Thickness of bottom	3.0	±.01	....
Length of interior cavity	22.45	±.01	....
Thickness of walls at 5.6 inches from base	2.56	....	....
Thickness of walls at 16.7 inches from base	2.585	....	....
Eccentricity of axis of interior cavity..per cent. of caliber	....	....	1½
Diameter of screw-plug hole	2.6	±.01	....
Pitch of thread on screw-plug hole..........to the inch	6	....	....
Length of thread on screw-plug hole	3.0	....	....
	Pounds.		
Weight of projectile with plug	584	....	....
SABOT.	*Inches.*		
Radius for outside cup of base	3.15	±.01	....
Radius for inside cup of base	6.3		
Height of sabot	3.75		
Exterior diameter of sabot	11.97		
Thickness of base around plug	.4		
Thickness of parallel portion of base	.25		
Distance of cannelure from rear	.8		
Depth of cannelure	.35		
Maximum width of cannelure	.3		
	Pounds.		
Weight of sabot (computed)	24		
Weight of sabot and projectile	608	+10.1 − 6.1	....

Number of 610 pound 12-inch Eureka shell examined	80
Number rejected for defects in material or finish	2
Total number rejected	2
Total number accepted	78
Weight of heaviest one accepted (including sabot)..........lbs..	596
Weight of lightest one accepted (including sabot)..........lbs..	588
Weight of total number accepted (excluding sabot)..........lbs..	44,446.8
Mean weight of projectile (including sabot)..........lbs..	591.73
Number of sabots examined	[illegible]
Number of sabots rejected for erroneous dimensions (rough castings)	[illegible]
Number of sabots rejected for defects in material or finish	[illegible]
Total number of sabots rejected	[illegible]
Number of sabots accepted	[illegible]
Weight of total number accepted..lbs..	[illegible]
Mean weight of sabot..........do..	[illegible]
Weight of total number of shot and sabots accepted..........lbs..	[illegible]
Actual weight of base-plug (av'ge).do..	[illegible]

PHYSICAL PROPERTIES.

	Density (actual.)	Tenacity.				Sabot metal.
		Prescribed.	Actual.	Allowed variations.	Actual variations.	
ns....	From 7.0835 To 7.1301	25,000	From 27,643 To 30,582	−0	From +2,643 To +5,582	Copper, 75 parts. Zinc, 25 parts.
......	7.1156	....	29,164	....	+4,164	

hell bodies made after contract drawing. Sabots after drawing dated April 4, 1885.
rincipally due to inferior dimensions of drawing. Shipped to United States proving-
Hook, New Jersey, May 16, 1885.
I have carefully inspected the above-noted projectiles, and that they conform to the
scribed within the variations allowed; and, further, that the terms of the contract as
workmanship have been complied with in their manufacture.
cton: Shell bodies, November 7, 1884; sabots and shell complete, April 29, 1885.

R. BIRNIE, JR.,
Lieutenant of Ordnance, Inspector.

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ort of 610 *pound* 12-*inch ogival-headed Eureka shell for muzzle-loading rifled*
de for the United States Ordnance Department by West Point Foundry Asso-
West Point Foundry, under contract of Chief of Ordnance, U. S. Army, dated
884.

Subject of measurement.	Prescribed dimensions.	Allowed variations.	
PROJECTILE.	*Inches.*	*Inch.*	*Per ct.*
of cylindrical portion of body { rear	12.176	....	+ 2
{ front	2.6	....	
of conical portion of body	1.25	....	
of head	13.4	....	− 2
of base for sabot	2.6	± 05	....
ngth of projectile	33.776	....	± 1
er of cylindrical portion { rear	11.92	±.01	....
{ front	11.97		....
er of conical base under sabot { rear	11.32	±.01	....
{ front	11.72		....
of head	18.0	± 05	....
ess of bottom	3.0	± 01	....
of interior cavity	22.45	± 01	....
ess of walls at 5.6 inches from base	2.56	....	....
ess of walls at 16.7 inches from base	2.585	....	....
icity of axis of interior cavity . . per cent. of caliber	....	....	1¼
er of screw-plug hole	2.6	±.01	....
thread on screw-plug hole . . . . to the inch	.6		
of thread on screw-plug hole	3.0	....	....
	Lbs.		
of projectile with plug	584	....	....
SABOT.	*Inches.*		
for outside cup of base	4.65	±.01	....
for inside cup of base	6.3		
of sabot	3.75		
r diameter of sabot	11.97		
ess of base around plug	.4		
ess of parallel portion of base	.25		
e of cannelure from rear	.8		
f cannelure	.3		
m width of cannelure	.3		
	Lbs.		
of sabot (computed)	24.0	+9.1	....
of sabot and projectile	60.8	−6.1	....

pounds 12-inch Eureka ed	25
ccepted	25
iest one accepted (includ-	609
test one accepted (includ-	604
l number accepted (ex-)	14,654.5

Mean weight of projectile (including sabot)	607.12
Number of sabots examined	25
Number of sabots accepted	25
Weight of total number accepted	523.5
Mean weight of sabot	20.94
Weight of total number of shot and sabots accepted	15,178.0
Actual weight of base plug (average)	6.4

PHYSICAL PROPERTIES.

Specimen.	Density (actual.)	Tenacity.				Sabot metal.
		Prescribed.	Actual.	Allowed variations.	Actual variations.	
Eight specimens...	From 7.1199 To 7.3273	25,000	From 26,436 To 30,467	—0	From +1,436 To +5,467	Copper, 75 parts. Zinc, 25 parts.
Average......	7.2023	....	28,746	....	+3,746	

REMARKS.—Shell bodies made after drawing "corrected October 11, 1884;" "modified" sabots after drawing dated April 3, 1885, shipped to United States proving-ground, Sandy Hook, New Jersey, April 14, 1885.

I certify that I have carefully inspected the above-noted projectiles, and that they conform to the dimensions prescribed within the variations allowed; and, further, that the terms of the contract as to material and workmanship have been complied with in their manufacture.

Date of inspection.—Shell bodies, November 29, 1884; sabot and shell complete, April 13, 1885.

R. BIRNIE, JR.,
Lieutenant of Ordnance, Inspector.

Inspection report of 610 *pound* 12*-inch ogiral-headed Eureka shell for muzzle-loading rifled mortar, made for the United States Ordnance Department by West Point Foundry Association, at West Point Foundry, under contract of Chief of Ordnance, U. S. Army dated August* 7, 1884.

Subject of measurement.	Prescribed dimensions.	Allowed variations.	
PROJECTILE.	*Inches.*	*Inch.*	*Per ct.*
Length of cylindrical portion of body { rear	12.176	....	+3
Length of cylindrical portion of body { front	2.6	....	
Length of conical portion of body	1.25	....	
Length of head	13.4	....	−3
Length of base for sabot	2.6	±.05	....
Total length of projectile	33.776	....	±1
Diameter of cylindrical portion { rear	11.92	±.01	....
Diameter of cylindrical portion { front	11.97		....
Diameter of conical base under sabot { rear	11.32	±0.1	....
Diameter of conical base under sabot { front	11.72		....
Radius of head	18.0	±0 5	....
Thickness of bottom	3.0	±0.1	....
Length of interior cavity	22.45	±0.1	....
Thickness of walls at 5.6 inches from base	2.56	....	....
Thickness of walls at 16.7 inches from base	2.585	....	....
Eccentricity of axis of interior cavity. per cent. of caliber	....	....	1¼
Diameter of screw-plug hole	2.6	±.01	....
Pitch of thread on screw-plug hole ....to the inch	6	....	....
Length of thread on screw-plug hole	3.0	....	....
	Lbs.		
Weight of projectile with plug	584.	....	....
SABOT.	*Inches.*		
Radius for outside cup of base	3.15	±.01	....
Radius for inside cup of base	6.3		....
Height of sabot	3.75		....
Exterior diameter of sabot	11.97		....
Thickness of base around plug	.4		....
Thickness of parallel portion of base	.25		....
Distance of cannelure from rear	.8		....
Depth of cannelure	.35		....
Maximun width of cannelure	.3		....
	Lbs.		
Weight of sabot (computed)	24	....	....
Weight of sabot and projectile	6.08	+10.1 − 6.1	....

Number of 610 pound 12-inch Eureka shell examined	103
Number rejected for defects in material or finish	5
Total number rejected	5
Total number accepted	98
Weight of heaviest one accepted (including sabot)	613
Weight of lightest one accepted (including sabot)	598
Weight of total number accepted (excluding sabot)	57,026
Mean weight of projectile (including sabot)	603.61

Number of sabots examined	[illegible]
Number of sabots rejected for erroneous dimensions (rough castings)	6
Number of sabots rejected for defects in material or finish	4
Total number of sabots rejected	[illegible]
Number of sabots accepted	[illegible]
Weight of total number accepted	2,[illegible]
Mean weight of sabot	[illegible]
Weight of total number of shot and sabots accepted	59,[illegible]
Actual weight of base plug (average)	[illegible]

PHYSICAL PROPERTIES.

Specimen.	Density (actual).	Tenacity.				Sabot metal.
		Prescribed.	Actual.	Allowed variations.	Actual variations.	
ight specimens...	From 7.1119 To 7.3273	25,000	From 26,436 To 30,467	—0	From +1,436 To +5,467	Copper, 75 parts. Zinc, 25 parts.
Average......	7.2023	.. ....	28,746	.. ..	+3,746	

EMARKS.—One projectile in addition to the two hundred required to complete contract accepted der authority from the Chief of Ordnance, U. S. A., dated April 30, 1885. Shell bodies made after wing "corrected October 11, 1884;" sabots after drawing dated April 4, 1885. Shipped to United tes proving-ground, Sandy Hook, New Jersey, May 16, 1885.

certify that I have carefully inspected the above-noted projectiles, and that they conform to the nensions prescribed within the variations allowed; and, further, that the terms of the contract as material and workmanship have been complied with in their manufacture.

ate of inspection.—Shell bodies, November 29, 1884; sabots and shell complete, April 29, 1885.

R. BIRNIE, JR.,
Lieutenant of Ordnance, Inspector.

spection report of Eureka sabots for 12-inch ogival-headed shell for muzzle-loading rifled mortar, made for the United States Ordnance Department by West Point Foundry Association, at West Point Foundry, under contract of Chief of Ordnance, U. S. Army, dated August 7, 1884.

Subject of measurement.	Prescribed dimensions.	Allowed variations.
SABOT.	*Inches.*	
Radius for outside cup of base	3.15	±0.01
Radius for inside cup of base	6.3	
Height of sabot	3.75	
Exterior diameter of sabot	11.97	
Thickness of base around plug	.4	
Thickness of parallel portion of base	.25	
Distance of cannelure from rear	.8	
Depth of cannelure	.35	
Maximum width of canelure	.3	
Weight of sabot (computed)	24 pounds.	

ber of 12-inch Eureka sabots examined	209	Number of sabots rejected for defects in material or finish	4
ght of heaviest sabot accepted	23	Total number of sabots rejected	9
ght of lightest sabot accepted	21	Number of sabots accepted	200
ber of sabots examined	209	Weight of total number accepted	4,400
ber of sabots rejected for erroneous dinsions (rough castings)	5	Mean weight of sabot	22

Composition of sabot metal: Copper, 75; zinc, 25 parts.

EMARKS.—Made after drawing, dated April 4, 1885. Shipped to United States proving-ground y Hook, N. J., May 16, 1885.

ertify that I have carefully inspected the above-noted projectiles, and that they conform to the ensions prescribed within the variations allowed; and, further, that the terms of the contract as aterial and workmanshiphave been complied with in their manufacture.

ate of inspection, May 7, 1885.

R. BIRNIE, JR.,
Lieutenant of Ordnance, Inspector.

APPENDIX 40.

PACKING CASES FOR HEAVY PROJECTILES.

BY LIEUT. ROGERS BIRNIE, JR., ORDNANCE DEPARTMENT.

(2 plates.)

WEST POINT FOUNDRY,
Cold Spring, N. Y., September 26, 1885.

GENERAL: Pursuant to your instructions, I have the honor to submit the following description of the method of packing heavy projectiles, which was approved by you under date of May 1, 1885.

The packing barrels were originally designed to facilitate the handling in transportation of 12-inch breech-loading shot weighing from 700 to 800 pounds each, replacing the square boxes heretofore ordinarily used for packing projectiles.

In April of this year twenty-five 12-inch muzzle-loading rifled mortar shell, net weight 610 pounds, were packed in this way and shipped from this foundry to the proving ground at Sandy Hook, N. J. Upon an examination made after the arrival of the projectiles at that place, the following report was made:

THE ORDNANCE BOARD, U. S. A.
New York April 29, 1885.

Respectfully returned to the Chief of Ordnance, U. S. A.

Lieutenant Birnie's mode of packing possesses several advantages over that now in use, viz:

(1) The barrel is stronger than the box.

(2) If projectiles are piled for storage, the contact surfaces of barrels will be smaller than those of boxes, the ventilation will be better, and the packages will last longer.

(3) As the barrel can be rolled when the box would require loading on a truck, it is easier to handle.

(4) A coating of lacquer or vaseline is necessary to preserve projectiles from rust; the open joints of the barrel are, therefore, not regarded as objectionable.

It is recommended that Lieutenant Birnie's method of packing be adopted for heavy projectiles.

For the Board.

T. G. BAYLOR,
Colonel of Ordnance, President of Board.

From this it will be understood that projectiles of 8-inch caliber and upwards, which are intended to be placed in store, should be packed in the barrels. But if the projectiles are intended for immediate issue into service, those of less than 300-pounds weight will preferably be packed in the ordinary square box, which can be made more quickly and at less cost than the barrel. In all cases the projectiles must be coated with vaseline or lacquer before packing.

Samples of the packing barrels made of pine are shown in Plates I and II, herewith, viz:

12-*inch breech-loading shot, weight* 800 *pounds* (Plate I).—The twelve staves, of equal width to correspond to the twelve sides of the base and ead, and 1.25 inches thick, extend the whole length of the case. The ase piece is 2 inches thick, and is recessed on the inner side to receive he head of the screw-plug, so that elsewhere it supports the base of he shot evenly. The diameter of the inscribed circle of the base is 1.94 inches, or the same as the diameter of the cylindrical portion of he shot at rear. The head is also 2 inches thick, but has a batten 1.25 nches thick on the inside face, which is bored through to receive and upport the point of the shot; this batten also serves to strengthen the ead and prevent it from splitting. Wrought nails are used to secure he batten. The inscribed diameter of the head piece is 12 inches, or early the same as the diameter of the cylindrical portion of the shot t front. The difference in the size of the head and base makes the xterior of the case slightly pyramidal in shape and allows contact beween the staves and the rear portion of the shot; each stave is lightly ecessed over the place of the band in order to clear it. The staves are astend to the head with 12*d.* nails, 2 in each end of each stave, thus equiring about 1 pound of these nails for each box. The barrel is held round with four bands of 1-inch hoop-iron punched and secured by rought nails to each stave. Two straps of this hoop-iron are likeise secured across the grain of the base of the barrel, as shown in the rawing, to prevent this piece from splitting.

In packing, the barrel is built around the projectile. The base piece eing laid on the floor, the projectile is raised and placed to rest verically upon it; the head is then rested upon the projectile and the staves astened. The marks placed upon the head of the barrel indicate the ind, caliber, and weight of projectile, and the place where manufactred.

12-inch muzzle-loading rifled mortar shell Eureka, weight 585 *pounds* Plate II).—This packing case differs essentially from the former only n the details of the base piece and recesses in the staves, which are rranged to protect the sabot in transportation. With the Eureka Arrick) sabot the head of the screw-plug is within the rim of the cup, nd it is necessary to place a thickness of board on the inner face of he base piece of the barrel to support the weight of the projectile gainst the head of the screw-plug. This piece is 0.75 of an inch thick nd bored through for the head of the base fuze; it supports the head f the screw-plug but does not bear upon the sabot; moreover, being ailed to the base piece of the barrel, it serves as a batten and renders he use of the outside cross-straps of hoop-iron unnecessary.

Nomenclature.—These examples illustrate the general designs of arrels adapted to packing the present service projectiles. The packing arrel consists of, 1, the base piece; 2, the head piece; 3, the staves; , the base batten; 5, the head batten; 6, the hoops; 7, the base straps. When the base batten is used the base straps may be omitted, and the everse.

The base and head pieces should be made from boards planed on one ide; a pattern is used to lay out the figure on the smooth side, and the pieces are then shaped with a saw. The lumber used for the staves need not be planed or the staves themselves dressed after being sawed ut. They can readily be made of uniform size and placed around the projectile with joints slightly open at the most. The recesses for the ands are made in the staves by taking a shallow sawcut at each side f the recess and afterwards removing the intermediate portion by and labor; these recesses in no case need exceed 0.125 of an inch in epth.

MODIFICATIONS OF THE DRAWINGS WITH DIFFERENT PROJECTILES AND CALIBERS.

Number of sides.—For 8-inch projectiles the barrels should be made *six*-sided, for 10 inch projectiles *eight*-sided, and for 12-inch and larger calibers *twelve*-sided.

The head and base pieces.—For 8-inch projectiles the head, which is always battened, may be made 1.5 inches thick, with a batten 1.0 inch thick, and the base also 1.5 inches thick when it is battened, as in the case of muzzle-loading projectiles with a sabot like the Arrick, but it should be 2 inches thick if the head of the screw plug be countersunk, as with breech loading projectiles or muzzle-loading projectiles of the Butler kind. For 10 inch projectiles and above, the thickness of the head or base should not be less than 2 inches, and for projectiles of over 800 pounds weight the thickness of the base piece should be increased to 2.5 or 3 inches.

The staves.—Up to 10-inch calibers inclusive, a thickness of 1 inch is sufficient for the staves; larger calibers will require a thickness of 1.25 inches. The staves need not be recessed for the sabot in cases where they would not press injuriously upon it, as, for instance, with the present 8-inch muzzle-loading Butler or Arrick projectiles, where the sabot forms a continuation of the straight cylindrical portion of the projectile.[*]

The head batten.—This is necessary with all projectiles; a thickness of 1 inch will suffice for projectiles up to 10-inch calibers or others not much exceeding 600 pounds in weight. For larger or heavier projectiles the thickness should not be less than 1.25 inches.

The base batten.—This is used only when necessary to protect such sabots as the Arrick, its thickness being such as to clear the rim of the cup from the base of the barrel whilst supporting the head of the screw-plug of the projectile; but to be effective as a batten the thickness should not be less than 0.625 of an inch.

The hoops.—Eight-inch projectiles will need only three bands of hoop-iron; with longer barrels than shown on the drawing, for the 800-pound 12-inch shot, a greater number than four may be found expedient.

The base straps.—These must be used and placed across the grain of the base piece to prevent splitting, when the latter is not secured by a batten.

Very respectfully, your obedient servant,

R. BIRNIE, JR.,
Lieutenant of Ordnance.

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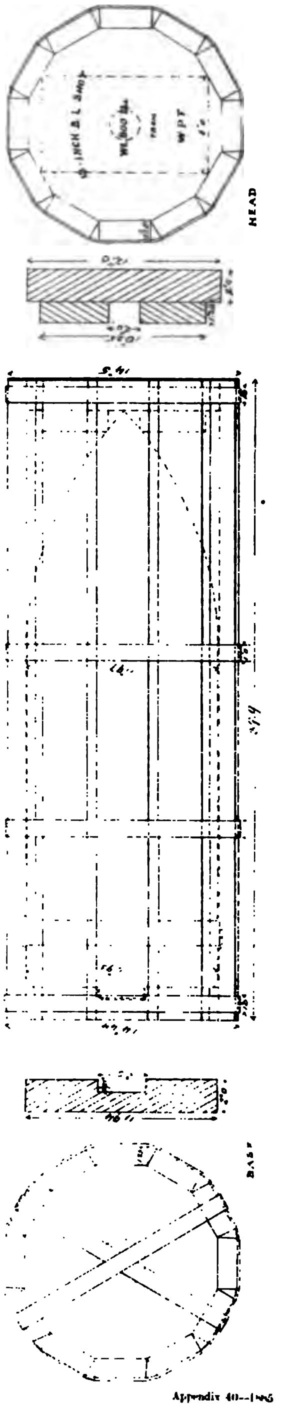
[*] In cases of this kind, also, the base, and head pieces would be of equal size and the staves of the barrel parallel instead of convergent, as indicated in the drawings given.

PLATE I.

PACKING BARREL FOR BREECH-LOADING PROJECTILES



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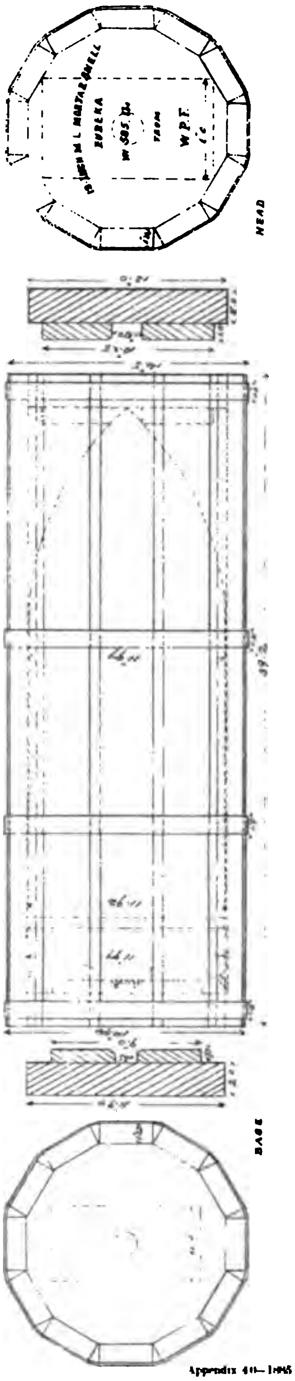
PACKING BARREL FOR EUREKA MUZZLE-LOADING PROJECTILES



Appendix 41—1885

APPENDIX 41.

TION REPORT OF 8 AND 10 INCH CORED CAST-IRON SHOT, WITH SABOTS OR BANDS, FOR BREECH-LOADING RIFLES, MADE AT WEST POINT FOUNDRY.

BY LIEUT. ROGERS BIRNIE, JR., ORDNANCE DEPARTMENT.

(1 plate.)

WEST POINT FOUNDRY,
Cold Spring, N. Y., September 21, 1885.

RAL: I have the honor to submit herewith inspection reports
llowing projectiles made at this foundry under contract of April
, viz:

ine 180-pound 8-inch cored cast-iron shot.
ne 235-pound 8-inch cored cast-iron shot.
ndred and six 285-pound 8-inch cored cast-iron shot.
undred and one 450-pound 10-inch cored cast-iron shot.

projectiles, intended for 8 and 10 inch breech-loading rifles,
pared for service, except banding, and have been temporarily
nd stored at this place.
ccompanying drawing shows the dimensions of the projectiles
. After casting a few samples of each kind it was found neces-
add to the dimensions of original designs in order to obtain the
d weights, as follows: With the 235-pound 8-inch shot 0.5 of an
th the 285-pound 8-inch shot 0.3 of an inch, and with the 10-inch
of an inch was added to the cylindrical body at the base.
wing the usual method of manufacture at this foundry, all shot
st point down, with metal taken directly from the air furnace,
e fed (except for the 180-pound shot, for which there was but
ling head) with hot metal and stirring rods through two small
n diametrically opposite sides of the core. The bases were cast
ed dimensions, except a small "boss," left for machine finish-
e part under the head of the base plug. The metal was drawn
all ladle, holding from 1,600 to 1,800 pounds. This method of
the base to finished dimensions is ordinarily followed at this
, and the hard skin thus left on the casting is believed to be
geous to the strength of the shot independent of the cost of
ion. But, unless the iron for the charge is carefully selected,
ficult to fulfill the requirements of the manufacture by this
. The upper surface of the casting is liable to be unsound. In
sent case the number of castings rejected by reason of defective
mounted to nearly 10 per cent. of the whole, and has led the
s to consider the propriety in the future of casting large pro-
with a sinking head several inches high over the whole of the
However, former experience here has shown, in the casting of
shot from 700 to 800 pounds weight, and also with varying cali-
wn to 8-inch, that with an entirely suitable mixture of iron
hly satisfactory shot can be made in the most economical man-
casting the base to finished size, as before indicated. The use of
dings for the stirring rods becomes necessary when the cores
g, since feeding upon one side alone disturbs the position of the
d is liable to render the shot eccentric.
ollowing table gives a record of the castings and tests of metal,
g composition of the charge, for each lot of castings:

Record of castings and tests of metal—Cored cast-iron shot—Contract April 25, 1885.

[10-inch, 450-pound shot.]

Date.	Castings, number of.			Charge of iron in percentages.									Tests.		Average weights.		Remarks.
	Made.	Accepted.	Rejected.	Amenia No.3.	Amenia No.4.	Gere No.2.	Hudson No.1.	Poughkeepsie No.2.	Gun scrap.	Old shot.	Air-furnace scrap.	Broken cupola castings.	Specific gravity.	Tenacity.	Rough.	Finished (without plug).	
1885.																	
May 13...	10	10	......	......	......	26.5	8.8	......	......	17.7	17.7	20.1	7.2722	28,521	450.1	442.6	Diameter of cylinder of pattern increased from 0''.1875 to 0''.25 surplus for finish, and length of cylinder increased 0''.2.
May 18...	23	19	4	......	......	24.8	12.4	......	16.1	8.1	16.8	21.7	7.2259	31,057	467.2	444.1	
May 20...	20	20	......	......	......	27.9	11.2	......	......	5.6	27.9	27.3	7.2801	32,180	468.3	447.5	
May 22 ..	23	18	5	......	......	32.4	......	......	......	11.0	32.4	24.0	7.2190	30,156	469.1	449.3	
May 25...	22	17	5	......	......	25.0	9.0	......	5.6	......	35.6	24.5	7.2729	32,310	468.5	446.8	
May 27...	25	16	9	......	......	31.0	10.0	......	5.9	......	43.4	9.6	7.3720	27,823	470.9	450.8	
May 29...	25	21	4	......	......	29.1	6.8	......	5.5	11.0	35.0	13.4	7.3167	33,986	469.7	448.4	Weight of screw-plug, 2.5 pounds (average).
June 3...	25	21	4	5.3	5.3	26.9	10.8	......	......	......	32.0	19.3	7.2921	32,939	472.3	448.5	
June 5...	25	25	......	5.4	5.4	16.3	10.9	......	......	27.7	16.3	17.9	7.3572	32,310	472.4	450.6	
June 8...	25	22	3	5.3	5.3	36.8	10.5	......	......	......	21.0	21.0	7.1927	28,668	470.0	445.1	
June 10...	25	18	7	17.4	....	8.1	23.2	......	...	14.0	23.2	14.0	7.2423	28,721	472.4	446.7	
June 12...	25	16	9	18.7	......	......	35.7	..	5.5	8.2	27.4	4.4	7.2827	30,705	473.6	448.9	
June 15...	25	22	3	......	5.7	34.3	22.9	......	......	8.6	17.1	11.4	7.2366	30,514	469.2	444.5	
June 17 ..	25	17	8	....	8.6	34.3	22.9	......	......	20.0	14.3	......	7.2641	31,413	470.3	446.2	
June 19...	25	17	8	......	7.8	31.2	20.8	......	......	11.4	28.6	......	7.2655	29,618	472.6	447.1	
June 29...	12	7	5	....	5.7	42.9	17.1	5.7	......	......	17.1	11.4	7.0956	27,600	465.0	439.2	
June 30 ..	20	5	......	....	......	41.4	24.1	......	......	20.7	13.8	......	7.1373	26,254	465.5	439.0	

[8-inch, 285-pound shot.]

Date.	Made.	Accepted.	Rejected.	Amenia No.3.	Amenia No.4.	Gere No.2.	Hudson No.1.	Poughkeepsie No.2.	Gun scrap.	Old shot.	Air-furnace scrap.	Broken cupola castings.	Specific gravity.	Tenacity.	Rough.	Finished (without plug).	Remarks.
May 25...	2	......	2	......	......	25.0	9.0	......	5.6	......	35.6	24.5	7.2729	32,310	291.6	....	Sample castings.
June 29...	16	13	3	......	5.7	42.9	17.1	5.7	......	......	17.1	11.4	7.0956	27,600	291.3	278.6	
July 2...	25	....	25	.....	8.0	42.4	24.2	......	......	12.1	18.1	......	7.1050	25,535	290.0	....	Rejected for inferior tenacity of metal.
July 7...	25	20	5	......	......	43.7	18.7	......	......	12.5	25.0	......	7.1291	28,237	290.0	278.8	
July 11...	27	24	3	......	......	35.9	16.1	......	......	23.9	23.9	......	7.2850	28,681	296.9	284.9	Length of cylinder increased 0''.3.
July 15...	43	40	3	......	......	33.3	22.2	......	......	22.2	22.2	......	7.1677	28,461	296.4	282.3	
July 18...	50	46	4	......	......	32.0	20.0	......	......	25.0	22.0	......	7.2234	31,009	297.4	284.2	
July 21 ..	27	34	12	......	......	32.0	20.0	......	......	25.0	22.0	......	7.3251	27,918	300.2	286.5	Weight of screw-plug, 2 pounds (average).
July 28...	19			......	......	26.1	20.1	......	......	17.4	17.4	......					
Aug. 1...	30	29	1	......	......	......	27.0	......	......	27.9	27.9	......	7.2171	27,154	299.7	[illegible]	

July 21...	3	......	3	......	......	32.0	20.0	......	......	25.0	22.0	......	7.3337	27,064	236.8	......	Sample castings.
July 27...	52	47	5	......	......	19.4	35.5	......	......	16.1	28.8	......	7.2430	26,613	242.8	232.7	Length of cylinder increased 0".5.
Aug. 1...	5	4	1	......	7.0	......	37.0	......	......	27.9	27.9	......	7.2471	27,154	243.2	232.5	Weight of screw-plug, 1.65 pounds (average).

[8-inch, 180-pound shot.]

May 18...	5	4	1	......	......	24.8	12.4	......	16.1	8.1	16.8	21.7	7.2259	31,057	188.8	182.5	Weight of screw-plug, 1.5 pounds (average).
July 2...	25	23	2	......	3.0	42.4	24.2	......	......	12.1	18.1	......	7.1050	25,535	186.2	180.0	
July 7...	25	25	......	......	......	43.7	18.7	......	......	12.5	25.0	......	7.1291	28,237	186.2	180.0	
July 11...	10	7	3	......	....	35.9	16.1	......	......	23.9	23.9	......	7.2850	28,681	188.1	182.3	

It will be seen that the above mixtures, with a few exceptions, produced iron of the required tenacity, 28,000 pounds per square inch, and of suitable specific gravity, placing the desirable lower limit for this last at 7.13. There was a relatively large number of rejected castings, principally for defects in the metal, due principally, it is believed, to the use of air-furnace scrap (sprue-heads, &c.) lacking in cleanliness. The introduction of a certain amount of remelted air-furnace castings is highly beneficial to the strength, and in this case the founders used the only material of this kind at hand, to their ultimate loss, however, in the close inspection which each projectile receives before it is accepted. Where gun-scrap is obtainable, a mixture of this with a soft anthracite and a medium charcoal pig is found to produce good results.

Of the different grades of pig-iron used, the Amenia and Gere are charcoal irons and the Hudson and Poughkeepsie anthracite irons. The Amenia, produced at the Wassaic Furnace, Dutchess County, New York, has come into notice within the past few years. A specimen taken from No. 3 pig and tested at this foundry June 3, 1885, gave a tenacity of 18,848, and one of No. 4 tested at the same time gave 40,388 pounds per square inch. The Gere iron is produced at Port Leyden (near Syracuse), N. Y. Recent tests of the No. 2 pig at this foundry gave tenacities varying from 14,385 to 16,219 pounds per square inch. The Hudson iron has given satisfaction in continued use at this foundry.

The specific gravity and tenacity were determined for each lot cast by taking a specimen from one of the shot, which was cut in two across the largest cross-section of the core. The specimen was then removed from the exposed face of the base portion with a hollow boring tool, taking the axis of the specimen parallel to that of the shot.

Very respectfully, your obedient servant,

R. BIRNIE, JR.,
Lieutenant of Ordnance.

Inspection report of 180-pound 8-inch ogival-headed, cored cast-iron shot, without sabots or bands, for breech-loading rifles, made for the United States Ordnance Department by West Point Foundry Association, at West Point Foundry, under contract of Chief of Ordnance, U. S. Army, dated April 25, 1885.

Subject of measurement.	Prescribed dimensions.	Allowed variations.
PROJECTILE.		
	Inches.	*Inch.*
Length of cylindrical portion of body	10.538	−0.21
Length of head	8.902	−0.17
Total length of projectile	19.44	±0.19
Diameter of cylindrical portion	7.95	±0.01
Radius of head	12.0	±0.05
Thickness of bottom	2.3	±0.1
Length of interior cavity	10.25	±0.1
Thickness of walls at 4.05 inches from base	2.225	±0.1
Eccentricity of axis of interior cavity	1¼ per cent. of caliber.	
Diameter of screw plug hole	1.5	±0.01
Pitch of thread on screw-plug hole	8 to the inch.	
Length of thread on screw-plug hole	2.3	±0.1
	Lbs. oz.	
Weight of screw plug	1 5	
Weight of projectile with screw plug	180 0	−1.8 +2.7

Number of 180-pound 8-inch cored cast-iron shot examined	65	Total number rejected	6
Number rejected for eccentricity of interior cavity	2	Total number accepted	[illegible]
Number rejected for defects in material or finish	4	Weight of heaviest one accepted...lbs..	[illegible]
		Weight of lightest one accepted ....do..	[illegible]
		Weight of total number accepted ...do..	[illegible]
		Mean weight of projectile .... do..	[illegible]

PHYSICAL PROPERTIES.

Specimen.	Density (actual).	Tenacity.			
		Prescribed.	Actual.	Allowed variations.	Actual variations.
Mean of four specimens, one from each lot cast	From 7.1291 To 7.2850	27,000	From 25,535 To 31,057	−2,000	From −1,465 To +4,057
Average	7.1935	....	28,377	....	+1,377

Remarks.—Boxed, with covers lightly fastened, to provide for removal when banding is required, and stored at West Point Foundry.

I certify that I have carefully inspected the above-noted projectiles, and that they conform to the dimensions prescribed within the variations allowed; and, further, that the terms of the contract as to material and workmanship have been complied with in their manufacture.

Date of inspection, August 14, 1885.

R. BIRNIE, Jr.,
Lieutenant of Ordnance, Inspector.

Inspection report of 235-pound 8-inch ogival-headed cored cast-iron shot, without sabots or bands, for breech-loading rifles, made for the United States Ordnance Department by West Point Foundry Association, at West Point Foundry, under contract of Chief of Ordnance, U. S. Army, dated April 25, 1885.

Subject of measurement.	Prescribed dimensions.	Allowed variations.
PROJECTILE.	*Inches.*	*Inch.*
Length of cylindrical portion of body	9.45	+0.19
	2.75	±0.05
Length of conical portion of body	1.25	
Length of head	10.55	−0.21
Total length of projectile	24.0	±0.24
Diameter of cylindrical portion, rear	7.93	±0.01
Diameter of cylindrical portion, front	7.97	
Radius of head	16.0	±0.05
Thickness of bottom	2.75	±0.1
Length of interior cavity	10.15	±0.1
Thickness of walls at 4 0 inches from base	2.715	±0.1
Thickness of walls at 9.9 inches from base	2.715	
Eccentricity of axis of interior cavity	1¼ per cent. of caliber.	
Diameter of screw-plug hole	1.5	±0.01
Pitch of thread on screw-plug hole	8 to the inch.	
Length of thread on screw-plug hole	2.75	±0.1
	Pounds.	
Weight of screw-plug	1 65	....
Weight of projectile with screw-plug	235 0	−2.35 +3.52

Number of 235-pound 8-inch cored cast-iron shot examined	60	Total number rejected	9
Number rejected for eccentricity of interior cavity	2	Total number accepted	51
Number rejected for defects in material or finish	7	Weight of heaviest one accepted...lbs..	236
		Weight of lightest one accepted ....do..	233
		Weight of total number accepted ..do..	11,969
		Mean weight of projectile ....do..	234.7

PHYSICAL PROPERTIES.

Specimen.	Density (actual).	Tenacity.		
		Prescribed.	Actual.	Actual variations.
Mean of two specimens, one from each lot cast	From 7.2430 To 7.2471	27,000	From 26,613 To 27,154	From −387 To +154
Average	7.2450	....	26,884	−116

Remarks.—Boxed, with covers lightly fastened, to provide for removal when required; to be banded and stored at West Point Foundry.

I certify that I have carefully inspected the above-noted projectiles, and that they conform to the dimensions prescribed within the variations allowed; and, further, that the terms of the contract as to material and workmanship have been complied with in their manufacture.

Date of inspection, August 14, 1885.

R. BIRNIE, Jr.,
Lieutenant of Ordnance, Inspector.

Inspection report of 285-pound 8-inch ogival-headed, cored, cast-iron shot, without [illegible] bands, for breech-loading rifles, made for the United States Ordnance Depart[illegible] West Point Foundry Association, at West Point Foundry, under contract of Chief of O[illegible]nance, U. S. Army, dated April 25, 1885.

PARTIALLY PREPARED FOR SERVICE.

Subject of measurement.	Prescribed dimensions.	Allowed variations.
PROJECTILE.	*Inches.*	*Inch.*
Length of cylindrical portion of body, rear	13.75	+0.27
Length of cylindrical portion of body, front	2.75	±0.05
Length of conical portion of body	1.25	
Length of head	10.55	−0.21
Total length of projectile	28.30	±0.28
Diameter of cylindrical portion, rear	7.98	±0.01
Diameter of cylindrical portion, front	7.97	
Radius of head	16.0	±0.05
Thickness of bottom	2.5	±0.1
Length of interior cavity	13.15	±0.1
Thickness of walls at 4.75 inches from base	2.715	±0.1
Thickness of walls at 13.65 inches from base	2.715	
Eccentricity of axis of interior cavity	1¼ per cent. of caliber.	
Diameter of screw-plug hole	1.5	±0.01
Pitch of thread on screw-plug hole	8 per inch.	
Length of thread on screw-plug hole	3.5	±0.1
	Pounds.	
Weight of screw-plug	2.0	
Weight of projectile with screw-plug	285.0	−2.85 +4.27

Number of 285-pound 8-inch cored cast-iron shot examined	264
Number rejected for erroneous dimensions of interior cavity	2
Number rejected for eccentricity of interior cavity	10
Number rejected for defects in material or finish	46
Total number rejected	[illegible]
Total number accepted	[illegible]
Weight of heaviest one accepted...lbs.	[illegible]
Weight of lightest one accepted...do.	[illegible]
Weight of total number accepted...do.	[illegible]
Mean weight of projectile...do.	[illegible]

PHYSICAL PROPERTIES.

Specimen.	Density (actual).	Tenacity.		
		Prescribed.	Actual.	Actual variations.
Mean of seven specimens, one from each lot cast	From 7.0956 To 7.3251	27,000	From 27,154 To 31,009	From + 154 To +4,[illegible]
Average	7.2104		28,350	−1,350

REMARKS.—The weight of twelve of the shot accepted was raised to standard by adding 3 p[illegible] to the base-plug, which was lengthened by screwing in an iron rod extending through the cor[illegible] point. Projectiles boxed, with covers lightly fastened, to provide for removal when banding is req[illegible] and stored at West Point Foundry.

I certify that I have carefully inspected the above-noted projectiles, and that they conform [illegible] dimensions prescribed within the variations allowed; and, further, that the terms of the contr[illegible] to material and workmanship have been complied with in their manufacture.

Date of inspection, August 14, 1885.

R. BIRNIE, JR.,
Lieutenant of Ordnance, Insp[illegible]

report of 450-pound 10-inch ogival-headed, cored, cast-iron shot, without sabots or or breech-loading rifles made for the United States Ordnance Department by West oundry Association, at West Point Foundry, under contract of Chief of Ordnance, rmy, dated April 25, 1885.

PARTIALLY PREPARED FOR SERVICE.

Subject of measurement.	Prescribed dimentions.	Allowed variations.
PROJECTILE.		
	Inches.	*Inch.*
Length of cylindrical portion of body { rear...	12.99	+0.25
Length of cylindrical portion of body { front...	2.75	±0.05
Length of conical portion of body..............	1.25	
Length of head..............................	13.21	−0.26
Total length of projectile....................	30.20	±0.30
Diameter of cylindrical portion { rear........	9.93	±0.01
Diameter of cylindrical portion { front........	9.97	
Radius of head..............................	20.0	±0.05
Thickness of bottom..........................	3.0	±0.1
Length of interior cavity.....................	14.56	±0.1
Thickness of walls at 5.19 inches from base...	2.78	±0.15
Eccentricity of axis of interior cavity.........	1¼ per cent. of caliber.	
Diameter of screw-plug hole..................	1.75	±0.01
Pitch of thread on screw-plug hole...........	6 per inch.	
Length of thread on screw-plug hole...........	3.0	±0.1
	Pounds.	
Weight of screw-plug........................	2.5	....
Weight of projectile with screw-plug.........	450.0	−4.5 +6.75

f 450-pound 10-inch cored cast- ; examined........................	380
jected for erroneous dimensions r cavity..................	5
ejected for eccentricity of inter- y..............................	1
jected for defects in material or	73

Total number rejected..................	79
Total number accepted..................	301
Weight of heaviest one accepted ..lbs..	455
Weight of lightest one accepted ...do..	444
Weight of total number accepted..do...	135,168
Mean weight of projectile.........do...	449.06

PHYSICAL PROPERTIES.

Specimen.	Density (actual.)	Tenacity.		
		Prescribed.	Actual.	Actual variations.
n of seventeen specimens, e from each lot cast......	From 7.0956 To 7.3720	27,000	From 26,254 To 33,986	From − 7.46 To +69.86
Average................	7 2549	....	30,281	+32.81

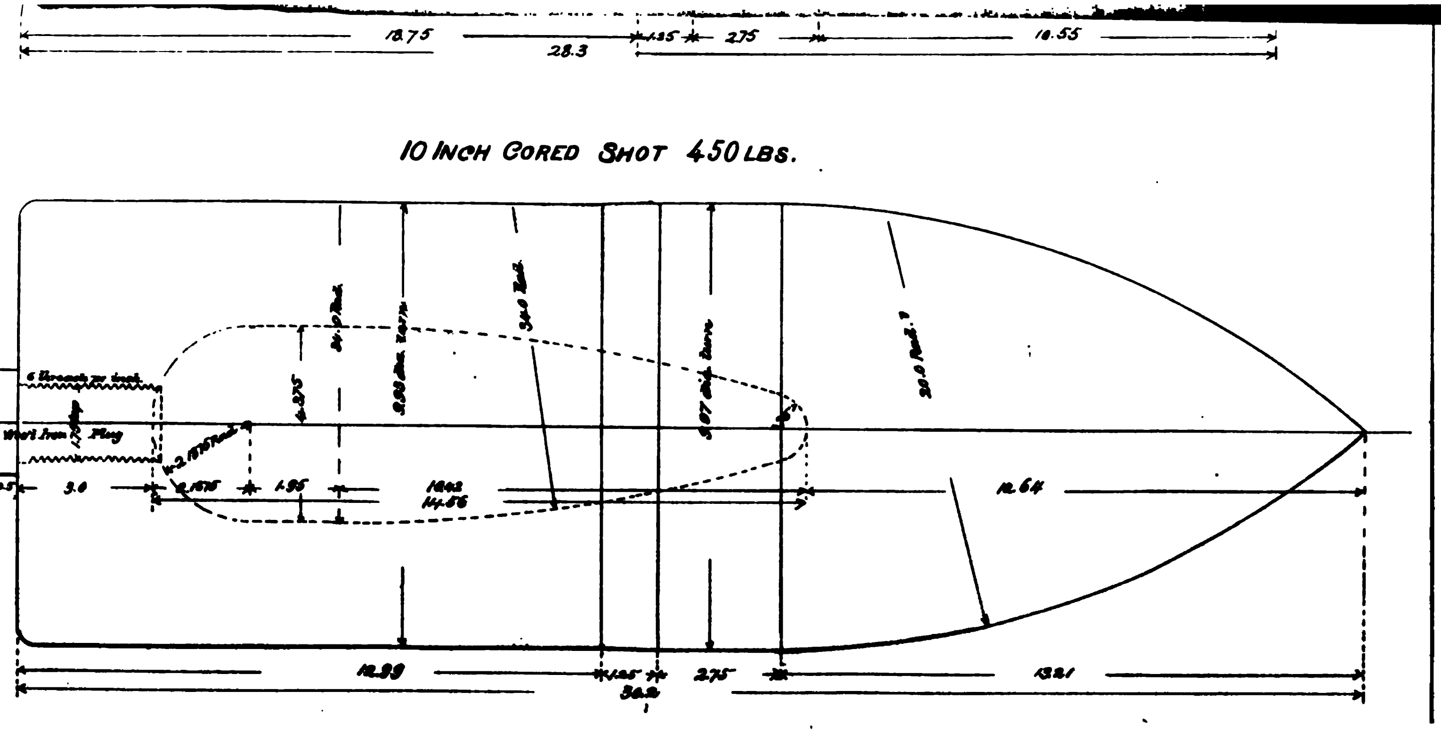
s.—The weight of twenty-two of the shot accepted was raised to standard by adding 4 the base-plug, which was lengthened by screwing in an iron rod extending through the core t. Projectiles boxed, with covers lightly fastened, to provide for removal when banding is and stored at West Point Foundry.

that I have carefully inspected the above-noted projectiles, and that they conform to the s prescribed within the variations allowed; and, further, that the terms of the contract as l and workmanship have been complied with in their manufacture.

inspection, July 11, 1885.

R. BIRNIE, JR.,
Lieutenant of Ordnance, Inspector.

10 INCH CORED SHOT 450 LBS.



APPENDIX 42.

ORT ON RECONSTRUCTION OF CONVERTED 8-INCH RIFLE NO. 68 (BREECH INSERTION).

By Lieut. Rogers Birnie, Jr., Ordnance Department.

June 10, 1885.

ENERAL: I have the honor to transmit herewith the following re-
s pertaining to the reconstruction of converted 8-inch rifle No. 68,
ech insertion), the inner tube of which, made by Paulding Kemble,
., under contract dated June 12, 1883, for the original gun, failed
er the firing proof at Sandy Hook, New Jersey, July 26, 1884, viz:
echanical tests of two specimens of 2¼-inch square Phœnix bar-iron
. for making the new inner tube.
spection of coiled wrought-iron tube No. 68 (duplicate).
spection of converted 8-inch rifle No. 68 (duplicate) with record of
surements with star-gauge and calipers.

his is the first instance in which any other iron of domestic man-
ture than the Ulster has been used for making these coiled
ght-iron tubes. At the time the iron was needed for this tube
Ulster works were not in operation. After several ineffectual at-
pts to obtain bar-iron of the requisite qualities elsewhere, a lot of
rs (sufficient to make the inner tube) was purchased from the
enix Iron Company. The tests of this iron herewith show that its
eral physical properties are equal to those of the Ulster iron.

he iron was accepted upon the results of the tests made as given.
s iron is not equal in purity to the Ulster iron, as shown by the
eral appearance of the metal when machine finished, but the bore
he finished tube is clean and free from serious flaws or cinder
ks.

n extracting the unserviceable tube from the casing after the muzzle-
ar, securing pin, and vent-piece had been removed, the whole tube
unscrewed and withdrawn cold. No heat was applied, as in a pre-
is case of the same kind.* In this gun it is certain that the two
nds to which it had been subjected in the firing proof had not "set"
tube out against the casing.

he jacket of the tube was also removed in this case without the
lication of heat. The inner tube was cut off near the muzzle end
he jacket; the portion within the bore of jacket was then bored out
within a few inches of the bottom until a shell of from 0.01 to 0.03
n inch in thickness was left. The bottom was then pierced through
eceive a strong bolt, which was passed through to the front of the
ket and furnished with a screw-thread at that end. A cross-head
next supported against the muzzle of the jacket and the shell of
tube withdrawn. The sides were so thin that no great resistance

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* See Report of the Chief of Ordnance, U. S. Army, for 1884, page 350.

was offered, and the jacket was found to be intact when freed from th tube. The same jacket was used in making the new tube; it was already threaded and fitted to the casing, and after being shrunk upo the new tube, when the chase and shoulder of the latter were turned t finished size, was finally assembled again in the gun casing without requiring additional finish except some slight hand-work.

In shrinking the jacket upon the tube the latter was not brough to a firm seat at bottom; a space of 0.1 of an inch was left between th base of the tube and the bottom of the jacket. This space was afterwards caulked by driving in the several segments of a wrought-iro ring, finished and fitted, to fill the empty space. The bottom of th cup, or base of the tube, finally received its usual support from the fac of the cast-iron breech-plug, which was carefully fitted to secure this end.

The failure of the original inner tube under the proof-firing was du to the same cause as in the case of the previous gun before referred to. This tube was not cut through the defects for examination, but the depression in the bore was examined after the tube was cut off. The depression is situated at the weld joint, between the two coiled sections, which form the middle of the tube, and besides the prominent depression mentioned by Lieut. C. W. Whipple, the officer in charge of the proving, viz, "about 0.15 of an inch deep, 1 inch wide, and crosses tw lands and grooves." It may now be seen, also, that a slight depressio completely encircles the bore at the same place.

Very respectfully, your obedient servant,

R. BIRNIE, JR.,
Lieutenant of Ordnance.

Report of inspection of coiled wrought-iron tube No. 68, breech insertion, manufactured the West Point Foundry, for 8-inch muzzle-loading rifle converted from 10-inch smoo bore Rodman gun, under contract with the Chief of Ordnance, U. S. Army, dated June 1883.

Subject of measurement.	Dimensions.		Variations.		Remarks.
	Prescribed.	Actual.	Allowed.	Actual.	
	Inches.	*Inches.*	*Inches.*	*Inches.*	
Total length of tube	147.66	....	....	....	Three inches surplus left at muzzle.
Total length of inner tube and jacket	140.41	....	....	....	
Projection of breech-plug in rear of tube	7.25	7.15	±0.05	−0.1	
Length of bore of tube	120.25	....	....	....	
Length of neck of tube	8.0	....	....	....	
Length of chase of tube	71.27	....	....	....	
Length of first reinforce of tube	8.73	....	....	....	
Length of second reinforce of tube	36.91	....	....	....	
Length of third reinforce of tube	7.0	....	....	....	
Length of fourth reinforce of tube	16.5	....	....	....	Left for threads.
Diameter of bore of tube	8.0	8.0	±0.03	0	Not rifled.
Diameter of neck of tube	9.75	9.748	±0.03	−0.002	
Diameter of chase of tube	10.8	....	....	....	Rough turned.
Diameter of first reinforce of tube	11.6	....	....	....	
Diameter of second reinforce of tube	13.6	....	....	....	
Diameter of third reinforce of tube	14.8	....	....	....	
Diameter of fourth reinforce of tube	15.6	....	....	....	
Length of muzzle-collar	7.0	....	....	....	
Diameter of muzzle-collar:					
Interior	9.76	9.758	±0.03	−0.002	
Exterior	11.85	....	....	....	Rough turned.
Play between muzzle-collar and neck of tube	0.01	0.01	....	0	
Incisions in muzzle-collar:					
Depth	0.875	....	....	....	
Width	2.0	....	....	....	
Total length of jacket	60.41	....	+0.01	....	

ort of inspection of coiled wrought-iron tube No. 68, &c.—Continued.

t of measurement.	Dimensions.		Variations.		Remarks.
	Prescribed.	Actual.	Allowed.	Actual.	
	Inches.	*Inches.*	*Inches.*	*Inches.*	
ket in rear of inner tube.	17.41	17.51	±0.05	+0.1	
ket over inner tube	43.0	42.9	±0.05	−0.1	
eter of jacket over inner	10.5	10.498	±0.01	−0.002	
eter of tube under jacket.	10.503	10 501		−0.002	
g shrinkage	0.003	0.003	....	....	
of inner tube	123.0	....	....	....	
ve at bottom of bore of	1.20	1.20	±0.01		
ve at bottom of tube....	1.25	1.25		....	
wels (two) for securing ket........................	2.0	2.0	....	....	
lowels for securing tube	0.75	0.75	....	....	
wrought-iron cup at bot-	2.75	2.75	±0.05	....	
of cup....................	5.5	5.05	±0.05	....	
interior of cup:					
....	7.0	7.0	±0.01	....	
....	4.6	4.6	±0.01	....	The omissions in "Actual dimensions" arise from the fact that the tube was finished and inserted in the casing at this foundry (authority, Chief of Ordnance, U. S. Army, per indorsement dated August 9, 1884). The finished dimensions appear on Inspection report of gun No. 68, herewith.
up over threads.........	7.8	7.8	±0.01	....	
d on cup	3 to the inch.		8 to the inch.		
of cast-iron breech-plug.	24.66	24.66	±0.01	....	
eech-plug within jacket..	17.41	17.51	±0.05	+0.1	
ead on breech-plug......	16.41	16.51	....	+0.1	
reech-plug over threads.	7.0	7.0	±0.01	....	
d on breech-plug	0.25	0.25	....	....	
houlder on breech plug..	9.75	9.75	....	....	
f shoulder, including ion........................	1.25	1.15	....	−0.1	
are at base of plug	6.0	6.0	....	....	
at base of plug.........	5.0	5.0	....	....	
uring-pin through shoul-	4.25	4.25	....	....	
securing-pin through plug	1.0	1.0	....	....	

PHYSICAL PROPERTIES.

nens.	Area of cross-section.	Density.	Tenacity.	Hardness.	Elastic limit.	Elongation per inch at rupture.	Remarks.
inch speci-	0.2538	7.6637	49,440	9.785	24,000	0.284	Phœnix bar-iron, 2¾ inches square, for inner tube.
inch speci-	0.2556	......	49,500	......	26,000	0.305	Ulster "B" iron, 2¾ inches square, for jacket.
inch speci-	0.2552	......	49,000	......	22,000	0.297	Ulster "B" iron, 4 × 3¾ × 3⅜ inches for jacket.
n..........	....	7.2259	31,057	......	....	....	Cast-iron for breech-plug.

EMARKS.—Hydraulic test of tube: Pressure of 120 pounds applied to inner tube when
for assemblage with jacket. This tube was made to replace original tube No. 68, com-
, 1884, which failed under firing proof at United States Proving Ground, Sandy Hook,
cket of the old tube, as fitted to the gun casing at the South Boston Iron Works, was
old tube without injury and used again for this tube. The inner tube and breech-cup,
reech-plug, and the muzzle-collar are new. The new inner tube was made from Phœnix
physical qualities of this iron, together with those of the Ulster bar-iron used in making
cket, are given above. In shrinking the jacket upon the tube, the latter was not firmly
om—a space of 0.1 of an inch being left open. By authority of the Chief of Ordnance,
lated May 27, 1885, the contractors were allowed to calk this space with neatly fitted
thin wrought-iron plate, the final acceptance of the tube by the United States in such
e determined by the action of the gun under the firing proof.
of tube: Finished and inserted in casing at West Point Foundry.

t the foregoing report is correct, and that the 8-inch coiled wrought-iron tube therein
een accepted by me as conforming to the standards as to dimensions, quality of mate-
acter of workmanship prescribed by the Ordnance Department.
ection, June 8, 1885.

R. BIRNIE, Jr.,
Lieutenant of Ordnance, Inspector.

Record of measurements with star-gauge and calipers of 8-inch muzzle-loading converted rifle No. 68 breech insertion.

Distance from muzzle.	Diameter of bore of casing.		Exterior diameter of tube.	Diameter of bore before proof.	Distance from muzzle.	Diameter of bore of casing.		Exterior diameter of tube.	Diameter of bore before proof.
	Horizontal.	Vertical.				Horizontal.	Vertical.		
Inch.	*Inches.*	*Inches.*	*Inches.*	*Inches.*	*Inch.*	*Inches.*	*Inches.*	*Inches.*	*Inches.*
1	....	....	9.746	8.000	62	10.500	10.500	10.487	8.000
2	....	....	9.746	8.000	63	10.500	10.500	10.4875	8.000
3	....	....	9.748	8.0005	64	10.499	10.500	10.488	8.000
4	....	....	9.750	8.0005	65	10.500	10.500	10.488	8.000
5	....	....	9.752	8.0005	66	10.499	10.500	10.4885	8.000
6	....	....	10.4875	8.0005	67	10.499	10.500	10.488	8.000
7	10.501	10.501	10.487	8.0005	68	10.499	10.500	10.4875	8.000
8	10.501	10.501	10.487	8.0005	69	11.495	11.496	11.4865	8.000
9	10.501	10.501	10.4885	8.0005	70	11.499	11.498	11.4865	8.000
10	10.501	10.501	10.4885	8.000	71	11.500	11.498	11.4875	8.000
11	10.501	10.501	10.488	8.000	72	11.501	11.499	11.487	8.000
12	10.501	10.501	10.487	8.000	73	11.502	11.500	11.4885	8.000
13	10.501	10.501	10.486	8.000	74	11.502	11.500	11.4875	8.000
14	10.500	10.501	10.4855	8.000	75	11.502	11.501	11.4875	8.000
15	10.501	10.501	10.4855	8.000	76	11.502	11.501	11.487	8.000
16	10.501	10.501	10.4865	8.000	77	....	....	....	8.000
17	10.501	10.501	10.4865	8.000	78	....	....	....	8.000
18	10.500	10.501	10.4855	8.000	79	....	....	....	8.000
19	10.500	10.501	10.485	8.000	80	....	....	13.4995	8.000
20	10.500	10.500	10.486	8.000	81	13.508	13.508	13.4995	8.000
21	10.501	10.500	10.486	8.000	82	13.508	13.508	13.5005	8.000
22	10.500	10.501	10.487	8.000	83	13.508	13.508	13.5015	8.000
23	10.500	10.500	10.487	8.000	84	13.509	13.508	13.503	8.000
24	10.500	10.501	10.4875	8.000	85	13.509	13.508	13.504	8.000
25	10.501	10.501	10.4875	8.000	86	13.509	13.508	13.504	8.000
26	10.501	10.500	10.487	8.000	87	13.509	13.508	13.5045	8.000
27	10.501	10.500	10.487	8.000	88	13.509	13.508	13.5045	8.000
28	10.500	10.500	10.487	8.000	89	13.509	13.509	13.5045	8.000
29	10.500	10.500	10.4865	8.000	90	13.510	13.509	13.5045	8.000
30	10.500	10.500	10.4865	8.000	91	13.510	13.509	13.504	8.000
31	10.500	10.500	10.4865	8.000	92	13.510	13.509	13.5035	8.000
32	10.500	10.500	10.4865	8.000	93	13.510	13.509	13.5035	8.000
33	10.500	10.500	10.4865	8.000	94	13.510	13.509	13.5035	8.000
34	10.500	10.500	10.486	8.000	95	13.510	13.510	13.5035	8.000
35	10.500	10.500	10.486	8.000	96	13.510	13.510	13.5035	8.000
36	10.500	10.500	10.486	8.000	97	13.510	13.510	13.5035	8.000
37	10.500	10.500	10.4865	8.000	98	13.509	13.509	13.504	8.000
38	10.500	10.500	10.486	8.000	99	13.509	13.510	13.5045	8.000
39	10.500	10.500	10.4855	8.000	100	13.510	13.510	13.5045	8.000
40	10.500	10.500	10.4855	8.000	101	13.510	13.509	13.5055	8.000
41	10.500	10.500	10.487	8.000	102	13.510	13.509	13.5075	8.000
42	10.500	10.500	10.4875	8.000	103	13.512	13.510	13.508	8.000
43	10.500	10.500	10.4865	8.000	104	13.512	13.510	13.5085	8.000
44	10.500	10.500	10.4865	8.000	105	13.512	13.510	13.5075	8.000
45	10.500	10.500	10.4865	8.000	106	13.512	13.509	13.507	8.000
46	10.500	10.500	10.4865	8.000	107	13.513	13.509	13.507	8.000
47	10.500	10.500	10.486	8.000	108	13.513	13.509	13.506	8.000
48	10.500	10.500	10.4875	8.000	109	13.512	13.509	13.5055	8.000
49	10.500	10.500	10.4875	8.000	110	13.512	13.509	13.505	8.000
50	10.500	10.500	10.487	8.000	111	13.512	13.508	13.505	8.000
51	10.500	10.500	10.4865	8.000	112	13.511	13.508	13.5055	8.000
52	10.500	10.500	10.4865	8.000	113	13.513	13.513	13.504	8.000
53	10.500	10.500	10.4865	8.000	114	....	....	....	8.000
54	10.500	10.500	10.486	8.000	115	14.698	14.698	14.6925	....
55	10.500	10.500	10.4865	8.000	116	14.698	14.698	14.6925	....
56	10.500	10.500	10.4865	8.000	117	14.698	14.698	14.693	....
57	10.500	10.500	10.487	8.000	118	14.698	14.698	14.693	....
58	10.500	10.500	10.4865	8.000	119	14.698	14.698	14.693	....
59	10.500	10.500	10.4865	8.000	120	14.698	14.698	14.694	....
60	10.500	10.500	10.4865	8.000	121	14.698	14.698	14.693	....
61	10.500	10.500	10.4865	8.000	122	14.698	14.698	....	....

***Record of measurements with star-gauge and calipers, &c.*—Continued.**

Distance from muzzle.	Diameter of bore across grooves.	Distance from muzzle.	Diameter of bore across grooves.
Inch.	*Inches.*	*Inch.*	*Inches.*
4	8. 164	64	8. 153
14	8. 162	74	8. 150
24	8. 161	84	8. 149
34	8. 159	94	8. 147
44	8. 158	104	8. 156
54	8. 154		

men of Phœnix bar iron, marked P H 1, taken with the fiber from lot of 2½-inch square bars, received January* 6, 1885, *at West Point Foundry.

th of specimen between shoulders: Original, 3.00 inches; after rupture, 3.811 inches. Diameter of specimen: Original, 0.568 inch; after rupture, 0.440, 0.445 inch; mean, 0.4425 inch.]

Weight applied.	Measurements.		Weight applied.	Measurements.	
	Under stress.	Relieved from stress.		Under stress.	Relieved from stress.
Pounds.	*Inch.*	*Inch.*	*Pounds.*	*Inch.*	*Inch.*
253. 4	. 252	. 252	6, 588. 4	. 259	. 256
506. 8	. 252	. 252	6, 841. 8	. 265	. 262
760. 2	. 252	. 252	7, 095. 2	. 270	. 267
1, 013. 6	. 252	. 252	7, 348. 6	....	....
1, 267. 0	. 252	. 252	7, 602. 0	....	....
1, 520. 4	. 252	. 252	7, 855. 4	....	....
1, 773. 8	. 252	. 252	8, 108. 8	....	....
2, 027. 2	. 252	. 252	8, 362. 2	....	....
2, 280. 6	. 252	. 252	8, 615. 6	....	....
2. 534. 0	. 252	. 252	8, 869. 0	....	....
2, 787. 4	. 252	. 252	9, 122. 4	....	....
3, 040. 8	. 252	. 252	9, 375. 8	....	....
3, 294. 2	. 252	. 252	9, 629. 2	....	....
3, 547. 6	. 253	. 252	9. 882 6	....	....
3, 801. 0	. 253	. 252	10, 136. 0	....	....
4, 054. 4	. 253	. 252	10, 389. 4	....	....
4, 307. 8	. 253	. 252	10, 642 8	....	....
4, 561. 2	. 253	. 252	10, 896. 2	....	....
4, 814. 6	. 253	. 252	11, 149. 6	....	....
5, 068. 0	. 253	. 252	11, 403. 0	....	....
5, 321 4	. 253	. 252	11, 656 4	....	....
5, 574. 8	. 253	. 252	11. 909. 8	....	....
5, 828. 2	. 253	. 252	12, 163. 2	....	....
6, 081. 6	. 254	. 252	12, 500	....	*1. 073
6, 335. 0	. 256	. 254	....	....	....

* Specimen broke.

re applied for test of hardness..pounds.. 10, 000
onding length of cut ....inch.. .702

RKS.—It was impossible to get half specimens accurately together, so an allowance was made inch. Cut from the end of one of eight bars submitted by Paulding, Kemble & Co., and intended fabrication of an inner tube, contract of June 12, 1883, for fifty 8-inch coiled wrought-iron tubes, insertion.
d at United States Proving Ground, Sandy Hook, N. J., January 14, 1885.
d by—

WM. M. MEDCALFE,
Lieutenant of Ordnance.

Table of deduced results.

Weight per square inch of original area.	Extension per inch in length.	Successive extension per inch in length.	Restoration per inch in length.	Successive restoration per inch in length.	Permanent set per inch in length.	Successive permanent set per inch in length.
Pounds.	*Inch.*	*Inch.*	*Inch.*	*Inch.*	*Inch.*	*Inch.*
1, 000						
* * *						
14, 000	.0003⅓	.0003⅓	.0003⅓	.0003⅓		
15, 000	.0003⅓	0	.0003⅓	0		
16, 000	.0003⅓	0	.0003⅓	0		
17, 000	.0003⅓	0	.0003⅓	0		
18, 000	.0003⅓	0	.0003⅓	0		
19, 000	.0003⅓	0	.0003⅓	0		
20, 000	.0003⅓	0	.0003⅓	0		
21, 000	.0003⅓	0	.0003⅓	0		
22, 000	.0003⅓	0	.0003⅓	0		
23, 000	.0003⅓	0	.0003⅓	0		
24, 000	.0006⅔	.0003⅓	.0006⅔	.0003⅓		
25, 000	.0013⅓	.0006⅔	.0006⅔	0	.0006⅔	.0006⅔
26, 000	.0023⅓	.001	.001	.0003⅓	.0013⅓	.0006⅔
27, 000	.0043⅓	.002	.001	0	.0033⅓	.002
28, 000	.00 6	.0016⅔	.001	0	.005	.0016⅔
* * *						
49, 300	.2736⅔	.2676⅔				

GENERAL SUMMARY.

Specific gravity		7.680
Hardness		9.64
Elastic limit	pounds..	24,000
Extension per inch at elastic limit	inch..	0.00066
Ultimate resistance per square inch of original area	pounds..	49,330
Ultimate extension per inch	inch..	0.27
Ratio of elastic to ultimate resistance		2.05
Original area of cross-section	square inch..	0.25
Contraction in area at fracture	per cent..	38.3
Ultimate resistance per square inch of fractional area	pounds..	81,280

Specimen of Phœnix bar iron, marked PH 2, taken with the fiber from lot of 2½-inch squ. bars, received January 6, 1885, at West Point Foundry.

[Length of specimen between shoulders: Original, 3.00 inches; after rupture, 3.894 inches. Diameter of specimen: Original, 0.569 inch; after rupture, 0.440 inch.]

Weight applied.	Measurements. Under stress.	Measurements. Relieved from stress.	Weight applied.	Measurements. Under stress.	Measurements. Relieved from stress.
Pounds.	*Inch.*	*Inch.*	*Pounds.*	*Inch.*	*Inch.*
254. 3	.276	.276	6, 611. 8	.284	.280
508. 6	.276	.276	6, 866. 1	.289	.286
762. 9	.276	.276	7, 120. 4	.295	.291
1, 017. 2	.276	.276	7, 374. 7		
1, 271. 5	.276	.276	7, 629. 0		
1, 525. 8	.277	.276	7, 883. 3		
1, 780. 1	.277	.276	8, 137. 6		
2, 034. 4	.277	.276	8, 391. 9		
2, 288. 7	.277	.276	8, 646. 2		
2, 543. 0	.277	.276	8, 900. 5		
2, 797. 3	.277	.276	9, 154. 8		
3, 051. 6	.277	.276	9, 409. 1		
3, 305. 9	.277	.276	9, 663. 4		
3, 560. 2	.278	.276	9, 917. 7		
8, 814. 5	.278	.276	10, 172. 0		
4, 068. 8	.278	.276	10, 426. 3		
4, 323. 1	.278	.276	10, 680. 6		
4, 577. 4	.278	.276	10, 934. 9		
4, 831. 7	.278	.276	11, 189. 2		
5, 086. 0	.279	.276	11, 443. 5		
5, 340. 3	.279	.276	11, 697. 8		
5, 594. 6	.279	.276	11, 952. 1		
2, 848. 9	.279	.276	12, 206. 4		
6. 103. 2	.2795	.276	12, 460. 7		
6, 357. 5	.280	.277	12, 600		*1.170

* Specimen broke.

ssure applied for test of hardness ....pounds.. 10,000
responding length of cut ....inch.. .695

EMARKS.—Cut from the end of one of eight bars submitted by Paulding, Kemble & Co., and in-
ded for the fabrication of an inner tube, contract of June 12, 1883, for fifty 8-inch coiled wrought-
tubes, breech insertion.
ested at United States Proving Ground, Sandy Hook, N. J., January 14, 1885.
ested by—

WM. M. MEDCALFE,
Lieutenant of Ordnance.

Table of deduced results.

Weight per square inch of original area.	Extension per inch in length.	Successive extension per inch in length.	Restoration per inch in length.	Successive restoration per inch in length.	Permanent set per inch in length.	Successive permanent set per inch in length.
Pounds.	*Inch.*	*Inch.*	*Inch.*	*Inch.*	*Inch.*	*Inch.*
1,000						
* * *						
6,000	.0003⅓	.0003⅓	.0003⅓	.0003⅓		
7,000	.0003⅓	0	.0003⅓	0		
8,000	.0003⅓	0	.0003⅓	0		
9,000	.0003⅓	0	.0003⅓	0		
10,000	.0003⅓	0	.0003⅓	0		
11,000	.0003⅓	0	.0003⅓	0		
12,000	.0003⅓	0	.0003⅓	0		
13,000	.0003⅓	0	.0003⅓	0		
14,000	.0006⅔	.0003⅓	.0006⅔	.0003⅓		
15,000	.0006⅔	0	.0006⅔	0		
16,000	.0006⅔	0	.0006⅔	0		
17,000	.0006⅔	0	.0006⅔	0		
18,000	.0006⅔	0	.0006⅔	0		
19,000	.0006⅔	0	.0006⅔	0		
20,000	.001	.0003⅓	.001	.0003⅓		
21,000	.001	0	.001	0		
22,000	.001	0	.001	0		
23,000	.001	0	.001	0		
24,000	.0011⅔	.0001⅔	.0011⅔	.0001⅔		
25,000	.0013⅓	.0001⅔	.001	—.0001⅔	.0003⅓	.0003⅓
26,000	.0026⅔	.0013⅓	.0013⅓	.0003⅓	.0013⅓	.001
27,000	.0043⅓	.0016⅔	.001	—.0003⅓	.0033⅓	.002
28,000	.0063⅓	.002	.0013⅓	.0003⅓	.005	.0016⅔
* * *						
49,550	.298	.2916⅔				

GENERAL SUMMARY.

cific gravity		7.6455
rdness		9.93
stic limit	pounds..	24,000
tension per inch at elastic limit	inch..	0.00116
imate resistance per square inch of original area	pounds..	49,550
imate extension per inch	inch..	0.298
tio of elastic to ultimate resistance		2.06
ginal area of cross-section	square inch..	0.2543
ntraction in area at fracture	per cent..	40.2
imate resistance per square inch of fractured area	pounds..	82,865

APPENDIX 43.

REPORT OF THE ROLLING AND DRAWING INTO WIRE OF TWENTY SELECTED STEEL BILLETS AT THE TRENTON IRON WORKS, TRENTON, N. J.

BY LIEUT. WM. M. MEDCALFE, ORDNANCE DEPARTMENT.

In obedience to instructions from the Chief of Ordnance, the billets of two ingots, Nos. 75 and 48, were set aside to be rolled separately, in order to specially observe their manufacture, and ascertain, if possible, the cause of breaks occurring in the process of drawing, and such other accurate information as might prove valuable in future operations of the same nature.

The billets were of open-hearth steel and showed the following physical properties when tested at the Otis Works, Cleveland, Ohio:

	Tenacity per square inch.	Contraction of area.	Ultimate elongation.	Remarks.
INGOT NO. 75.				
	Pounds.	*Per ct.*	*Per ct.*	
Longitudinal specimen	75,360	60.41	33.7	Specimen taken from bottom end of top billet.
Transverse specimen	71,830	25.35	16.33	
INGOT NO. 48.				
First test.				
Longitudinal specimen	78,770	48.72	30.45	Specimen taken from top of top billet and the top billet rejected after this test.
Transverse specimen	74,860	18.57	13.5	
Second test.				
Longitudinal specimen	79,950	54.45	30.05	Additional test made of billet taken at random from those of the ingot.
Transverse specimen	76,430	19.41	19.83	
Third test.				
Longitudinal specimen	77,400	52.04	31.75	Additional test made of specimen taken from bottom end of top billet.
Transverse specimen	72,710	21.43	12.67	

The eleven billets of ingot No. 75 were taken to represent the best steel furnished under the contract with the Otis Iron and Steel Company, and the nine billets of ingot No. 48 to represent the worst.

The conversion of these billets into wire was begun May 23, and completed June 13. The process was watched by the inspector as far as to include the first draught, and thereafter by Mr. Frank E. Davis, from whose notes this report is largely compiled.

The billets were weighed before being placed in the heating furnace. They were withdrawn when they had acquired a full yellow heat, some being nearly white. The time of remaining in furnace varied from twenty-six to forty-three minutes, twenty-six minutes being required to give them a full heat.

As they were taken from the furnace they were immediately transferred to the rolls and reduced to ½-inch rods in nine passes. When rolled the billets appeared to be uniformly heated, and on leaving, the rolls showed, except in the first billet rolled, when a slight delay occurred, a bright red color. The time of passage through the rolls was about one and one-fourth minutes.

While still hot the billets were tagged with numbers and weighed. To more accurately determine the loss due to heating they were again weighed cold. The loss was found to be 2.47 per cent., which is much smaller than is usually expected by the manufacturer. This was probably due to the fact that no time was lost in removing the billets from the furnace when they had acquired a full heat.*

The usual loss in the case of cast-steel is 4.68 per cent., and instances on record in the company's books show a loss of 5.9 per cent.

The rods were tagged with numbers, the odd numbers from 1 to 17 inclusive, being attached to those of ingot 48, the remaining numbers up to 20, to those of ingot 75. The tags were retained throughout all the operations, so that the identity of each coil was known with certainty.

When cold the rods were pointed, the ends being heated in a blacksmith's fire, and hammered down to a tapered point. Where the end was defective a short piece was cut off, which necessitated the coils being reweighed after pointing.

The annealing took altogether twenty-nine hours, seven hours for the rods to acquire a full heat and twenty-two hours for cooling. When the rods were taken out the annealer was hot enough to blaze a piece of wood. Temperature estimated at 650° F.

The temperature of annealing was determined by the introduction of heat tests prepared by Dr. Woodbridge. They consisted of alloys of copper and tin, inclosed in short iron tubes. There were eight of these tests used; Nos. 1 and 5 were composed of 1 part tin, 3 parts copper; Nos. 2 and 6 of 1 part tin and 3½ parts copper; Nos. 3 and 7 of 1 part tin and 4 parts copper; Nos. 4 and 8 of 1 part tin and 5 parts copper; Nos. 1, 2, 3, and 4 were wired to the coil first placed in the annealer, and Nos. 5, 6, 7, and 8 to the last or top coil.

After annealing these tests were found to be as follows: Nos. 1 and 2, unaltered ; No. 3, slightly flattened; No. 4, unaltered; Nos. 5 and 6, considerably flattened; No. 7, melted; No. 8, unaltered.

These results would show that the hottest portion of the annealer is near the top. Why the more fusible alloys, Nos. 1, 2, 5 and 6, were the least affected is unexplained, unless the tests were placed in the wrong boxes. The temperature required to melt No. 7, assuming that it was correctly placed in its box, would be about 1,800° F., which represents the maximum temperature attained in the hottest portion of the annealer.†

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* Probably the most important circumstances connected with the small loss of weight in heating and rolling the billets into wire-rods are these:

The furnace, which has just been in use for heating *iron* billets, was at a higher heat than was required for steel, and therefore did not require much additional firing. Fuel was, however, abundantly supplied, but the blast was not urged.

These were circumstances very favorable to diminishing the oxidizing tendency of the furnace gases.—(W. C. Woodbridge).

† Subsequent trial of the order of fusibility of the specimens of the alloys used as heat tests in the annealing showed that they had been wrongly numbered. Using the numbers applied, they fused in the following order: No. 3, No. 2. No. 1, No. 4.—(W. C. Woodbridge.)

The pickling bath, newly prepared for these coils, contained 102 pounds of oil of vitriol and 3,131 pounds of water, or the proportion of 1 part oil of vitriol to 30.69 parts water. Its temperature was estimated to be about 100° F.

Wires Nos. 1, 2, 3, 4, 5, 6, 8, 9, 11, 12, 15, 16, 17, 19, and 20, were immersed 39 minutes; 7, 10, 13, 14, and 18, 49.5 minutes. As soon as removed from this bath the rods were washed and allowed to lie wet for a sufficient time, say 20 minutes, to acquire a " water coat." They were then lime coated and placed in the baking-oven to dry.

The lime coating consisted of 2 parts rye flour lees and 1 part milk of lime. The lees being prepared by stirring 2 or 3 pounds of rye flour in a barrel of water.

The baking lasted over night, occupying in all about fifteen hours. The oven was not of uniform temperature throughout. A piece of lead placed on one of the coils partially melted, which shows the temperature to be in the neighborhood of 630° F.

The coils were weighed after baking and the loss of weight in the pickling bath determined. It varied from 0.2 of a pound to 1.1 pounds, the mean loss being 0.63 of a pound. The rods were now ready for the draw-plate. After the second draught a coating of copper was applied to improve the smoothness of the surface. For this purpose they were immersed one by one in a solution of sulphate of copper with a small excess of sulphuric acid, and lay in it until a satisfactory coating of copper was obtained. After coating the coils were washed by playing on them with a hose, then lime coated and placed over the annealer to dry.

The time of immersion of the coils in the copper sulphate bath varies with the size of the wire, being over a half an hour after the second draught and only five or six minutes after the ninth draught.

Tallow was used as a lubricant in drawing. The following points were carefully noted by Mr. Davis during the drawing: Time, speed, and angle of draught; diameter of coil freely expanded when taken from drum; dimensions of the wire after each draught; taper of punch; observance of the rule of reversing wire after each draught, and breaks or other unusual occurrences. His notes in full on these points are hereto appended.

In adjusting the draw-plate the workmen give the plate a slight cant to the rear to introduce a bend in the wire, and, as they say, "kill it," or make it lie flat.

It was claimed that without this precaution the wire would become unmanageable when removed from the drum. At the request of Dr. Woodbridge two coils, Nos. 17 and 18, were drawn with the plate vertical. No such trouble as was anticipated resulted, the diameter of the freely expanded coils being only slightly greater than in the case of coils drawn in the usual way. If the physical tests to be made at Watertown Arsenal of specimens taken from the different coils show that the strength or elasticity of the wire is at all impaired by this bend, which, as suggested by Dr. Woodbridge, stretches in the draw-plate one side more than the other, I see no good reason why a perfect parallelism of the surface of the plate with the axis of the drum may not be insisted upon hereafter.

Mr. Davis's record of the breaks occurring during the drawing are appended. Most of them consisted merely in the tapered point breaking off. Four, however, deserve attention. Coil No. 9 broke on the fourth draught after drawing 7 feet. It was cut off, as the plate was gouging it badly on the under side. Coil No. 11 broke on the fourth draught, after the first third had been drawn. This also Mr. Davis considers was due to gouging of the draw-plate.

Coil No. 15 broke on the eighth draught after drawing seventeen coils. The plate was found to be gouging the under side of the wire. Coil No. 7 broke on the eighth draught, shortly before the completion of the draught. The fracture was short and diamond shaped. The remark that "the plate had been scraping one of the sides at the corner at which the fracture started" is not understood, but it seems to imply that in the opinion of Mr. Davis this break, as in the case of the others, was due to the imperfections of the plate.

All these breaks appear, then, to have been caused by the draw-plate itself. Undoubtedly this explains the breaking of the wire in many instances, although the nature of the lubricant has certainly had a great deal to do with it in the past. During the time that the wet process was used, and especially for a short period when glucose was employed, the breaks were, according to the statement of the workmen, much more frequent than at present with the use of tallow.

It is also to be remarked that all these breaks occurred in coils coming from ingot No. 48, selected as inferior to No. 75, and possessing considerable less ductility than the latter.

It was intended to preserve specimens of the broken wire and send them on for analysis. During my absence the broken pieces were, however, allowed to be thrown in the scrap heap and their identity lost.

A specimen, 4 feet in length, was taken from each finished coil, tagged with its proper number, and sent to Watertown Arsenal for physical test.

Heating and rolling.

No. of ingot.	No. of billet.	Time in furnace.	Heat to which billet was subjected.	Time of passage through rolls.	Heat at which rod left roll.	Weight before rolling.	Weight after rolling.	Loss of weight in heating.
				m. s.		*Pounds.*	*Pounds.*	*Pounds.*
48	1	26	Full yellow	1 75	Red	80.0	78.0	2.0
75	2	30	...do	1 30	Bright red	78.2	76.4	1.8
48	3	33	...do	1 20	....do	80.1	78.0	2.1
75	4	35	do	1 24	....do	81.3	79.8	1.5
48	5	37	Near white	1 15	Cherry	80.7	78.8	1.9
75	6	38	....do	1 12	Bright red	82.1	80.2	1.9
48	7	39	....do	1 15	do	79.2	77.15	2.05
75	8	40	Full yellow	1 10	Cherry	80.0	77.6	2.4
48	9	41	Near white	1 15	Bright red	80.1	77.9	2.2
75	10	43	Full yellow	1 15	....do	81.2	79.05	2.15
48	11	42	....do	1 13	Cherry	80.0	77.9	2.1
75	12	40	....do	1 18	Bright red	81.0	79.1	1.9
48	13	41	do	1 12	Cherry	81.0	78.9	2.1
75	14	42	Yellow	1 10	....do	81.8	80.0	1.8
48	15	42	Full yellow	1 18	Bright red	79.3	77.9	1.4
75	16	40	do	1 10	....do	80.6	79.0	1.6
48	17	40	.. do	1 10	.. do	79.5	77.2	2.3
75	18	41	Near white	1 12	....do	81.2	79.1	2.1
75	19	40	Full yellow	1 10	....do	80.8	78.5	2.3
75	20	38	....do	1 13	do	81.5	79.3	2.2

Time occupied in acquiring full heat, twenty-six minutes. Billet, when rolled, of uniform heat. Blast on most of time for thirteen minutes. First billet white on side nearest the fire; end generally white; black in places between billets, where they lie close together.

Loss of weight due to pickling.

No. of billet.	Weight after pointing.	Weight after pickling and baking.	Loss of weight.	No. of billet.	Weight after pointing.	Weight after pickling and baking.	Loss of weight.
	Pounds.	*Pounds.*	*Pounds.*		*Pounds.*	*Pounds.*	*Pounds.*
1	77.9	77.6	0.3	11	77.4	76.8	0.6
2	76.1	75.5	0.6	12	78.8	78.0	0.8
3	77.6	76.5	1.1	13	78.2	78.2	0.0
4	79.5	78.5	1.0	14	79.9	78.9	1.0
5	78.4	77.9	0.5	15	77.3	77.0	0.3
6	80.0	79.8	0.2	16	78.9	78.0	0.9
7	76.8	76.0	0.8	17	77.1	76.4	0.7
8	78.0	77.4	0.6	18	79.0	78.2	0.8
9	77.7	77.0	0.7	19	78.2	78.0	0.2
10	78.9	77.9	1.0	20	78.9	78.3	0.6

Time and speed of draught.

Number.	First draught.			Second draught.			Third draught.			Fourth draught.			Fifth draught.		
	Time.		Speed per second.	Time.		Speed per second.	Time.		Speed per second.	Time.		Speed per second.	Time.		Speed per second.
	m.	*s.*	*Feet.*	*m.*	*s.*	*Feet.*	*m.*	*s.*	*Feet.*	*m.*	*s.*	*Feet.*	*m.*	*s.*	*Feet.*
1			......	9	30	0.251	9	3	0.259	15	21	0.284	17	37	0.283
2	11	0	0.394	10	25	0.245	11	32	0.274	13	51	0.283	17	31	0.274
3	6	0	0.323	12	0	0.226	13	4	0.251	14	34	0.302	17	27	0.297
4	7	0	0.362	11	45	0.238	11	53	0.283	15	50	0.258	20	40	0.283
5	8	30	0.259	11	5	0.259	11	3	0.274	14	20	0.302	18	28	0.274
6	7	45	0.274	12	15	0.251	13	26	0.264	16	10	0.292	21	35	0.302
7	7	0	0.292	9	45	0.226	12	9	0.244	12	51	0.312	17	57	0.274
8	9	0	0.224	12	30	0.226	12	53	0.259	13*	13	0.312	19	31	0.266
9	8	0	0.266	10	47	0.251	13	11	0.248	12	13	0.323	18	47	0.302
10	8	0	0.251	12	30	0.215	11	45	0.323	16	7	0.271	20	12	0.283
11	7	30	0.283	10	10	0.238	13	48	0.232	11	39	0.302	14	46	0.302
12	8	0	0.266	12	3	0.232	12	15	0.226	15	1	0.274	21	40	0.266
13	8	45	0.238	10	26	0.238	12	2	0.266	16*	21	0.274	18	35	0.283
14	9	30	0.245	10	20	0.274	14	9	0.250	14	10	0.302	18	37	0.292
15	10	0	0.245	10	31	0.210	13*	15	0.266	14	44	0.312	18	46	0.283
16	8	45	0.232	12	26	0.219	13	35	0.235	14	46	0.312	16	59	0.323
17	7	45	0.266	10	25	0.245	13	12	0.259	14	29	0.302	20	24	0.266
18	8	30		10	0	0.259	13	36	0.248	14	58	0.292	20	27	0.283
19	7	30	0.238	8	50	0.238	12	12	0.250	13	26	0.302	15	41	0.258
20	8	0	0.220	10	42	0.259	12	59	0.259	14	1	0.312	20	47	0.238

The times of draught for the first hole are uncorrected for stoppage, which amounts to one-half to one minute.

The speed of draught was not always uniform throughout the draught of a single wire. The time given was taken after a few coils were on the drum, by noting the time of a single revolution. Diameter of drum, 34⅝ inches.

Time and speed of draught—Continued.

Number.	Sixth draught.		Seventh draught.		Eighth draught.		Ninth draught.		Tenth draught.	
	Time.	Speed per second.	Time.	Speed per second.	Time.	Speed per second.	Time.	Speed per second.	Time.	Speed per second.
	m. s.	Feet.	m. s.	Feet.	m. s.	Feet.	m. s.	Feet.	m. s.	Feet.
1	26 21	0.271	19 50	0.431	31 4	0.412	....	0.412	39 12	0.453
2	....	0.292	21 8	0.453	....	0.431	30 13	0.437	39 14	0.453
3	....	....	....	0.259	28 24	0.412	35 40	0.453	40 42	0.431
4	25 18	0.302	29 27	0.302	30 11	0.431	36 46	0.431	40 30	0.431
5	25 9	0.274	22 15	0.431	27 35	0.431	35 18	0.431	39 6	0.412
6	24 17	0.302	16 55	0.431	30 16	0.453	35 39	0.431	41 29	0.431
7	24 48	0.266	20 38	0.453	..	0.412	28 57	0.431	37 49	0.394
8	22 49	0.292	29 15	0.292	29 16	0.453	35 25	0.431	39 26	0.453
9	21 51	....	20 40	0.431	29 5	0.431	36 17	0.394	48 56	0.377
10	27 15	0.283	23 12	0.302	31 58	0.394	38 52	0.431	45 12	....
11	19 28	0.292	24 16	0.302	20 55	0.394	27 42	0.431	30 57	0.431
12	24 49	0.292	32 0	0.266	30 51	0.394	38 12	0.431	36 30	0.394
13	26 51	0.266	26 21	0.312	28 30	0.412	36 56	0.412	41 26	0.453
14	20 1	0.283	22 1	0.431	28 41	0.394	35 46	0.453	....	0.431
15	29 55	0.283	30 1	0.302	22 40	0.412	....	....	31 0	0.412
16	24 45	0.292	30 30	0.292	23 4	0.453	35 28	0.453	41 48	0.431
17	24 17	0.292	....	0.431	27 55	0.412	....	....	47 15	0.377
18	24 7	....	21 46	0.431	24 52	0.412	37 32	0.412	45 44	0.394
19	23 38	0.302	21 58	0.412	28 7	0.412	....	....	43 4	0.412
20	26 2	0.302	30 24	0.312	38 20	0.431	51 21	0.394	40 8	0.431

Circumference of drum, 9 065 feet.

Table showing dimensions of each wire after the different draughts.

FIRST DRAUGHT.

[Assigned standard, 0.445 inch.]

Number of rod.	Dimensions.					
	Front end.		Last end.		Difference between ends.	
	Rad.	Lat.	Rad.	Lat.	Rad.	Lat.
	Inch.	Inch.	Inch.	Inch.	Inch.	Inch.
1	.4305	.4415	.4405	.4425	.0010	.0010
2	.4400	.4423	.4407	.4425	.0007	.0002
3	.4400	.4425	.4407	.4430	.0007	.0005
4	.4407	.4425	.4415	.4433	.0008	.0008
5	.4405	.4425	.4415	.4435	.0010	.0010
6	.4405	.4430	.4415	.4435	.0010	.0005
7	.4420	.4440	.4410	.4430	.0010	.0010
8	.4410	.4430	.4415	.4435	.0005	.0005
9	.4410	.4432	.4415	.4440	.0005	.0008
10	.4408	.4435	.4420	.4440	.0012	.0005
11	.4410	.4435	.4425	.4445	.0015	.0010
12	.4415	.4435	.4425	.4440	.0010	.0008
13	.4415	.4435	.4427	.4445	.0012	.0010
14	.4420	.4445	.4420	.4440	.0000	.0005
15	.4400	.4408	.4410	.4418	.0010	.0010
16	.4406	.4410	.4410	.4415	.0004	.0005
17	.4410	.4420	.4420	.4430	.0010	.0010
18	.4413	.4420	.4420	.4425	.0005	.0005
19	.4400	.4405	.4410	.4415	.0010	.0010
20	.4410	.4410	.4415	.4420	.0005	.0010

Table showing dimensions of each wire after the different draughts—Continued.

SECOND DRAUGHT.

[Assigned standard, 0.3943 inch.]

Number of rod.		Dimensions.					
		Front end.		Last end.		Difference between ends.	
		Rad.	Lat.	Rad.	Lat.	Rad.	Lat.
		Inch.	*Inch.*	*Inch.*	*Inch.*	*Inch.*	*Inch.*
1	Reversed	.3910	.3905	.3915	.3910	.0005	.0005
2	......do	.3885	.3867	.3895	.3880	.0010	.0013
3	......do	.3838	.3835	.3805	.3797	.0033	.0038
4	......do	.3883	.3913	.3885	.3925	.0002	.0012
5	......do	.3852	.3870	.3860	.3886	.0008	.0016
6	......do	.3828	.3835	.3820	.3895	.0008	.0060*
7	......do	.3863	.3850	.3870	.3810	.0007	.0040*
8	......do	.3850	.3860	.3843	.3865	.0007	.0005*
9	......do	.3843	.3843	.3850	.3850	.0007	.0007*
10	......do	.3870	.3870	.3873	.3880	.0003	.0010*
11	......do	.3854	.3865	.3865	.3890	.0011	.0015*
12	......do	.3870	.3848	.3880	.3860	.0010	.0012*
13	......do	.3885	.3875	.3895	.3885	.0010	.0010
14	......do	.3843	.3826	.3855	.3840	.0012	.0014
15	......do	.3870	.3852	.3875	.3855	.0005	.0003*
16	......do	.3885	.3845	.3890	.3870	.0005	.0025*
17	......do	.3835	.3860	.3850	.3870	.0015	.0010
18	......do	.3835	.3870	.3865	.3883	.0030	.0013
19	......do	.3874	.3873	.3875	.3880	.0001	.0007
20	......do	.3885	.3880	.3890	.3894	.0005	.0014

THIRD DRAUGHT.

[Assigned standard, 0.3494 inch.]

Number of rod.		Front end. Rad.	Front end. Lat.	Last end. Rad.	Last end. Lat.	Difference. Rad.	Difference. Lat.
1	Reversed	.3425	.3430	.3442	.3435	.0017	.0005
2	......do	.3422	.3420	.3427	.3427	.0005	.0007
3	......do	.3405	.3420	.3435	.3432	.0030	.0012
4	......do	.3410	.3415	.3428	.3425	.0018	.0010
5	......do	.3420	.3405	.3430	.3415	.0010	.0010
6	......do	.3425	.3407	.3435	.3415	.0010	.0008
7	......do	.3434	.3412	.3440	.3419	.0006	.0007
8	......do	.3425	.3405	.3440	.3420	.0015	.0015
9	......do	.3395	.3380	.3410	.3390	.0015	.0010
10	......do	.3418	.3423	.3430	.3425	.0012	.0002
11	......do	.3420	.3422	.3435	.3432	.0015	.0010
12	Not reversed	.3420	.3428	.3436	.3438	.0016	.0010
13	Reversed	.3430	.3428	.3435	.3448	.0005	.0020
14	......do	.3418	.3410	.3420	.3418	.0002	.0008
15	......do	.3410	.3412	.3425	.3425	.0015	.0013
16	......do	.3405	.3415	.3424	.3418	.0019	.0003*
17	......do	.3390	.3388	.3408	.3400	.0018	.0012
18	......do	.3390	.3386	.3407	.3396	.0017	.0010
19	......do	.3435	.3428	.3445	.3437	.0010	.0009*
20	......do	.3425	.3425	.3435	.3432	.0010	.0007

Table showing dimensions of each wire after the different draughts—Continued.

FOURTH DRAUGHT.

[Assigned standard, 0.309 7 inch.]

Number of rod.		Dimensions.					
		Front end.		Last end.		Difference between ends.	
		Rad.	Lat.	Rad.	La .	Rad.	Lat.
		Inch.	*Inch.*	*Inch*	*Inch.*	*Inch.*	*Inch.*
1	Reversed	.2990	.3000	.3018	.3014	.0028	.0014
2	......do	.2975	.2980	.2985	.2985	.0010	.0005
3	......do	.3024	.3034	.3038	.3036	.0014	.0002
4	......do	.3005	.3018	.3026	.3026	.0021	.0008
5	......do	.3296	.3006	.3024	.3021	....	.0015
6	......do	.3004	.3014	.3020	.3022	.0016	.0008
7	......do	.3035	.3060	.3040	.3062	.0005	.0002
8	......do	.3000	.3013	.3020	.3020	.0020	.0007
9	Not reversed	.2998	.3010	.3015	.3020	.0017	.0010*
10	Reversed	.2980	.2988	.2978	.2992	.0002	.0004
11	......do	.3005	.3006	.3005	.3016	.0000	.0010
12	......do	.3030	.3034	.3043	.3045	.0013	.0011
13	......do	.3039	.3040	.3045	.3045	.0006	.0005
14	Not reversed	.3030	.3050	.3042	.3054	.0012	.0004
15	do	.3000	.3004	.3010	.3013	.0010	.0009
16	Reversed	.3005	.3003	.3012	.3010	.0007	.0007
17	......do	.3010	.3007	.3025	.3025	.0015	.0018
18	......do	.3010	.3018	.3020	.3025	.0010	.0007
19	......do	.3026	.3035	.3040	.3040	.0014	.0005
20	......do	.3035	.3043	.3040	.3048	.0005	.0005

FIFTH DRAUGHT.

[Assigned standard, inches 0.2744.]

1	Reversed	.2673	.2675	.2680	.2684	.0007	.0009
2	......do	.2635	.2635	.2640	.2645	.0005	.0010
3	......do	.2670	.2660	.2680	.2668	.0010	.0009
4	......do	.2622	.2630	.2630	2636	.0008	.0006
5	......do	.2640	.2630	.2655	.2642	.0015	.0012
6	......do	.2640	.2633	.2650	.2640	.0010	.0007
7	......do	.2636	.2632	.2655	.2645	.0019	.0013
8	Not reversed	.2626	.2634	.2636	.2639	.0010	.0005
9	......do	.2485	.2490	.2500	.2500	.0013	.0010*
10	Reversed	.2640	.2645	.2660	.2661	.0020	.0016
11	Not reversed	.2640	.2641	.2652	.2645	.0012	.0004
12	Reversed	.2642	.2640	.2657	.2648	.0015	.0008
13	......do	.2645	.2640	.2650	.2644	.0005	.0004
14	Not reversed	.2650	.2638	.2658	.2648	.0008	.0010
15	......do	.2670	.2665	.2685	.2675	.0015	.0010
16	Reversed	.2678	.2668	.2683	.2670	.0005	.0002
17	......do	.2620	.2625	.2653	.2636	.0033	.0011
18	Not reversed	.2640	.2635	.2650	.2640	.0010	.0005
19	Reversed	.2632	.2625	.2640	.2630	.0008	.0005
20	......do	.2634	.2638	.2645	.2644	.0011	.0006

Table showing the dimensions of each wire after the different draughts—Continued.

SIXTH DRAUGHT.

[Assigned standard, inches 0.2432.]

Number of rod.		Dimensions.					
		Front end.		Last end.		Difference between ends.	
		Rad.	Lat.	Rad.	Lat.	Rad.	Lat.
		Inch.	*Inch.*	*Inch.*	*Inch.*	*Inch.*	*Inch.*
1	Reversed	.2350	.2345	.2365	.2354	.0015	[illegible]
2		.2350	.2353	.2360	.2363	.0010	[illegible]
3	Reversed	.2350	.2340	.2365	.2350	.0015	[illegible]
4	......do	.2335	.2340	.2352	.2352	.0017	[illegible]
5	......do	.2335	.2355	.2365	.2365	.0030	[illegible]
6	......do	.2345	.2343	.2350	.2350	.0005	[illegible]
7	......do	.2347	.2346	.2360	.2356	.0013	[illegible]
8	......do	.2344	.2352	.2350	.2360	.0006	[illegible]
9	......do	.2368	.2366	.2375	.2375	.0007	[illegible]
10	Not reversed	.2340	.2349	.2350	.2348	.0016	[illegible]
11	Reversed	.2345	.2350	.2358	.2358	.0013	[illegible]
12	......do	.2348	.2363	.2365	.2368	.0017	[illegible]
13	......do	.2344	.2350	.2354	.2357	.0010	[illegible]
14	......do	.2364	.2350	.2375	.2360	.0011	[illegible]
15	......do	.2350	.2362	.2364	.2367	.0014	[illegible]
16	......do	.2347	.2346	.2356	.2356	.0009	[illegible]
17	......do	.2365	.2352	.2370	.2360	.0005	[illegible]
18	Not reversed	.2340	.2340	.2355	.2350	.0015	[illegible]
19	Reversed	.2348	.2342	.2360	.2350	.0012	[illegible]
20	......do	.2345	.2350	.2354	.2358	.0009	[illegible]

SEVENTH DRAUGHT.

[Assigned standard, 0.2155 inches.]

1	Reversed	.2075	.2084	.2090	.2095	.0015	[illegible]
2	......do	.2085	.2093	.2090	.2100	.0005	[illegible]
3	......do	.2057	.2060	.2070	.2070	.0013	[illegible]
4	......do	.2060	.2062	.2073	.2073	.0013	.0011
5	......do	.2075	.2065	.2084	.2080	.0009	[illegible]
6	......do	.2070	.2066	.2075	.2076	.0005	[illegible]
7	......do	.2095	.2095	.2150	.2100	.0055	[illegible]
8	......do	.2074	.2080	.2077	.2086	.0003	[illegible]
9	......do	.2083	.2078	.2090	.2085	.0007	[illegible]
10	......do	.2095	.2086	.2085	.2087	.0010	[illegible]
11	......do	.2070	.2080	.2064	.2075	.0006	[illegible]
12	......do	.2060	.2065	.2065	.2073	.0005	[illegible]
13	......do	.2060	.2072	.2075	.2080	.0015	[illegible]
14	......do	.2084	.2080	.2085	.2090	.0001	[illegible]
15	......do	.2065	.2084	.2075	.2088	.0010	[illegible]
16	......do	.2087	.2080	.2096	.2090	.0009	[illegible]
17	......do	.2080	.2080	.2100	.2092	.0020	[illegible]
18	......do	.2075	.2071	.2082	.2080	.0007	[illegible]
19	......do	.2060	.2064	.2075	.2073	.0015	[illegible]
20	......do	.2055	.2064	.2065	.2070	.0010	[illegible]

showing the dimensions of each wire after the different draughts—Continued.

EIGHTH DRAUGHT.

[Assigned standard, 0.1910 inches.]

	Dimensions.					
	Front end.		Last end.		Difference between ends.	
	Rad.	Lat.	Rad.	Lat.	Rad.	Lat.
	Inch.	*Inch.*	*Inch.*	*Inch.*	*Inch.*	*Inch.*
ersed	.1796	.1805	.1805	.1818	.0009	.0013
	.1802	.1802	.1813	.1813	.0011	.0011
ersed	.1790	.1800	.1795	.1808	.0005	.0008
.do	.1790	.1785	.1790	.1797	.0000	.0012
.do	.1804	.1794	.1825	.1815	.0021	.0021
.do	.1750	.1755	.1760	.1772	.0010	.0017
	.1810	.1816	.1815	.1820	.0005	.0004
reversed	.1786	.1776	...	...	...	...
	.1785	.1778	.1795	.1790	.0010	.0012
ersed	.1780	.1790	.1790	.1798	.0010	.0008
reversed	.1805	.1800	.1815	.1812	.0010	.0012
ersed	.1788	.1798	.1795	.1805	.0007	.0007
.do	.1805	.1800	.1815	.1812	.0010	.0012
.do	.1795	.1785	.1808	.1794	.0013	.0009
reversed	.1778	.1770	.1790	.1780	.0012	.0010
ersed	.1815	.1815	.1832	.1825	.0017	.0010
do	.1808	.1802	.1818	.1812	.0010	.0010
.do	.1808	.1804	.1820	.1816	.0012	.0012
.do	.1812	.1825	.1835	.1833	.0013	.0008
.do	.1870	.1866	.1828	.1825	.0042	.0041

NINTH DRAUGHT.

[Assigned standard, 0.1692 inches.]

reversed	...	...	...	...	...	...
ersed	.1600	.1605	.1605	.1610	.0005	.0005
.do	.1595	.1589	.1600	.1600	.0005	.0011
.do	.1585	.1588	.1589	.1594	.0004	.0006
.do	.1577	.1576	.1595	.1592	.0018	.0016
.do	.1587	.1585	.1595	.1592	.0008	.0007*
.do	.1610	.1613	.1618	.1620	.0008	.0007
.do	.1593	.1588	.1620	.1650	.0027	.0062
do	.1575	.1583	.1588	.1593	.0013	.0010
reversed	.1570	.1573	.1582	.1583	.0012	.0010
ersed	.1583	.1575	.1590	.1585	.0007	.0010
.do	.1585	.1588	.1595	.1596	.0010	.0008
do	.1574	.1578	.1584	.1587	.0010	.0009
.do	.1583	.1575	.1590	.1585	.0007	.0010
	.1590	.1600	.1594	.1620	.0004	.0020
ersed	.1596	.1595	.1605	.1603	.0009	.0008
.do	.1591	.1598	.1596	.1606	.0005	.0008
.do	.1567	.1580	.1580	.1588	.0013	.0008
	.1605	.1606	.1618	.1616	.0013	.0010
ersed	.1571	.1574	.1578	.1585	.0007	.0011

Table showing dimensions of each wire after the different draughts—Continued.

TENTH DRAUGHT.

[Required size, 0.15 inches.]

Number of rod.		Dimensions.					
		Front end.		Last end.		Difference between ends.	
		Rad.	Lat.	Rad.	Lat.	Rad.	Lat.
		Inch.	*Inch.*	*Inch.*	*Inch.*	*Inch.*	*Inch.*
1	Reversed	.1490	.1494	.1498	.1498	.0008	[illegible]
2	Not reversed	.1488	.1400	.1495	.1496	.0007	[illegible]
3	......do	.1490	.1490	.1495	.1495	.0005	[illegible]
4	Reversed	.1493	.1490	.1498	.1492	.0005	[illegible]
5	......do	.1498	.1492	.1505	.1500	.0007	[illegible]
6	......do	.1495	.1489	.1500	.1490	.0005	.0001
7		.1485	.1478	.1495	.1485	.0009	[illegible]
8	Reversed	.1485	.1488	.1491	.1496	.0006	[illegible]
9	......do	.1490	.1487	.1494	.1494	.0004	.0007
10	......do	.1491	.1494	.1493	.1496	.0002	.0002
11	Not reversed	.1490	.1495	.1498	.1502	.0008	.0007
12	Reversed	.1500	.1495	.1501	.1502	.0001	.0007
13	......do	.1493	.1494	.1500	.1500	.0007	[illegible]
14	......do	.1500	.1495	.1501	.1502	.0001	.0007
15	......do	.1490	.1496	.1494	.1502	.0004	[illegible]
16	......do	.1490	.1492	.1498	.1501	.0008	[illegible]
17	......do	.1490	.1485	.1497	.1488	.0007	[illegible]
18	......do	.1497	.1487	.1500	.1491	0003	[illegible]
19	......do	.1490	.1483	.1498	.1489	.0008	[illegible]
20	......do	.1493	.1493	.1500	.1500	.0007	.0007

The measurements in the foregoing table were made with micrometer calipers. When a wire was drawn without being reversed, it was generally because there was no point at the end to be drawn first or reversing. There was but one plate for each size of wire, containing from three to eight holes, according to the size of the wire. The same hole was not generally used twice in succession, but the plate was shifted. Occasionally it was necessary to stop to hammer up the holes. The stars at the right indicate when the plate was hammered up. When hammering was not sufficient to correct the size of hole it was necessary to heat the plate to a red heat and hammer it or batter the plate. The dimensions recorded are an average of three measurements, taken at point 2 or 3 feet from each end of the wire.

Angle of draught and diameter of coil.

No. of coil.	First.		Second.		Sixth.*		Fourth.		Fifth.		Third.		Seventh.		Eighth.		Ninth.		Tenth.	
	Angle.	Diameter.	Angle.	Diameter.	Angle.	Diameter.	Angle.	Diameter.	Angle.	Diameter.	Angle.	Diameter.	Angle.	Diameter.	Angle.	Diameter.	Angle.	Diameter.	Angle.	Diameter.
	°	In.	°	In.	°	In.	°	In.	°	In.	°	In.	°	In.	°	In.	°	In.	°	In.
1	....	......	5.1	....	3.6	38.5 34.	3.4	44¾	8.5	47.5	8.1	45½	4.6	44¼	3.1	36.5	....	38	5.1	....
2	....	......	3.6	..	3.8	40 35	....	42½	3.6	46.5	8.1	45½	6	44	....	38¾	3.4	35	4.6	....
3	....	......	6.1	....	4.6	38¾ 35¾	6.1	44½	8.4	......	....	46	2.6	42	3.3	37	3.1	35	4.8	....
4	....	......	....	43¾	4.1	38.5 36	5.8	43½	3.9	48	8.1	45½	3.1	39.5	3.1	41	2.6	40	7.1	....
5	....	......	5.6	44¼	5.1	38 35¼	4.1	43	3.1	46.5	4.6	44	1.4	42	2.8	40.5	2.9	....	6.1	....
6	....	......	5.1	44¾	6.3	37 35	5.8	43½	3.6	46.5	7.1	45.5	1.2	42.5	.5	43	2.8	40	4.5	....
7	....	......	6.1	44½	5.6	40 36	2.3	43	1.6	46.75	4.6	46¼	2.5	43.5	1.1	39.5	2.1	....	4.4	....
8	....	......	2.6	43	5.1	39¼ 35	4.3	44	3.1	47.75	6.6	46	4.1	40.5	2.6	38	3.2	35	3.9	....
9	....	......	2.6	44½	6.1	40.5 36	3.1	42½	3.9	44	8.1	45¼	4	43.5	....	40.5	4.1	36¾	5.0	....
10	....	......	2.6	45	3.1	39¼ 35½	..	43	5.1	46	7.1	46	4.1	41	3.1	39¾	4.0	34½	5.1	....
11	....	......	2.1	43	6.4	39¾ 36	4.4	45	2.1	46.5	3.1	44½	4.1	40	3.5	36	3.3	34½	1.9	....
12	....	......	3.6	44¼	3.9	39 34¾	3.1	43.5	2.1	45.5	4.6	45	3.6	40	3.1	41	2.9	34	....	....
13	....	......	5.1	45	4.1	39½ 36	3.5	44¾	3.1	46	5.1	45	3.6	....	4.0	37½	2.6	38½	5.1	....
14	....	......	4.1	44¼	5.1	38½ 35½	2.6	43¼	3.1	46¼	6.1	45¼	0.4	43.5	1.1	38	3.3	32	5.1	....
15	....	......	4.1	44¼	3.4	39 35½	3.1	43	3.6	46	5.1	45	4.1	41	2.9	....	....	37	3.1	....
16	....	......	2.6	45	5.6	39 36	3.4	45½	3.1	47	7.1	44.5	4.1	45	3.6	37	3.8	33½	2.8	....
17	0	48.25	0	....	0	48 36	0	47	1.3	54	0	48	0	54	4.1	50	0	45	0	....
18	0	......	0	....	0	40 36	0	48	0	56.5	0	49	....	55½	0	44	0	42	0.8	....
19	....	......	4.1	45.5	4.1	40¼ 36	4.6	44	1.6	47	7.7	45	1.6	43	1.9	....	....	34.5	4.3	....
20	....	......	4.1	45.5	3.9	39½ 36¼	3.6	44½	3.4	47	7.1	46	1.1	39½	3.4	36¾	1.6	36	4.4	....

* Sixth and third columns inserted in reversed order.

Time of immersion of rods in copper coating.

Number.	Number of draught subsequent to coating.							
	Third.	Fourth.	Fifth.	Sixth.	Seventh.	Eighth.	Ninth.	Tenth.
	s.	s.	s.	s.	s.	s.	s.	s.
1	53	23	8	12	5	7	6	5
2	45	22	16	8	5	6	6	3
3	50	16	23	10	11	3	7	6
4	30	......	15	......	5	9	11	6
5	38	31	40	11	8	9	4	6
6	35	16	15	13	......	7	6	3
7	38	18	......	......	5	7	3	6
8	40	18	23	......	7	13	6	5
9	50	20	16	10	6	7	7	6
10	42	18	16	14	6	10	7	6
11	......	18	12	8	8	8	5	6
12	......	18	......	......	6	9	9	6
13	......	15	......	......	11	9	4	5
14	......	13	......	......	4	9	6	6
15	......	23	12	12	5	5	6	7
16	......	18	18	10	4	5	7	6
17	52	18	......	......	6	7	6	7
18	65	......	......	......	......	6	5	5
19	......	22	16	15	......	7	9	5
20	......	16	13	9	7	11	6	6

SPECIAL NOTES.

Breaks occurring during drawing.

No. 11. Point broke in clamp on starting; second draught.
No. 14. Point broke in starting; second draught.
No. 15. Point broke in starting; second draught.
No. 11. Point broke in starting; third draught.
No 8. Point broke after drawing 2 feet; third draught.
No. 9. Point broke in starting; fourth draught.
No. 9. Point broke after drawing 7 feet: fourth draught. (Cut off, as plate was gouging badly on the under side.)
No. 10. Point broke in starting; fourth draught.
No. 11. Broke after first third had been drawn, due to gouging of the draw-plate; fourth draught.
No. 4. Point broke in starting; fourth draught.
No. 7. Point broke in starting; fourth draught.
No. 17. Point broke in starting; fourth draught.
No. 16. Broke after two feet had been drawn, fifth draught.
No. 8. Point broke in starting; seventh draught.
No. 11. Point broke in starting; eighth draught.
No. 13. Point broke in starting; eighth draught.
No. 15. After drawing 17 coils, plate was found to be gouging under side of wire and they were cut off; eighth draught.
No. 7. The wire broke before completing the draught, seven of the original coils being left. The fracture was short and of diamond shape. The plate had been scraping one of the sides at the corner at which the fracture started. Eighth draught.
No. 9. For the first half of the draught a fine, curling thread came from one corner of the wire. When it ceased coming a sharp corner was found on the wire. The shaving was due to a crack in the plate. In all the draughts there were a few shavings produced by this same cause.

There was considerable vibration in the drum of the drawing machine. The engine ran at a speed of two hundred and sixty revolutions per minute to produce one revolution of the drum in twenty-two seconds.

Near the close of the test it was discovered that the axis of the drum was not parallel with the plane of the slide-rest carrying the draw-plate. There is a difference of 1° between the two ends, the one end being lower than the other. A noticeable cant was produced in some of the wire, before and after finishing, by lack of parallelism between the sides of the hole in the draw-plate and the plane of the slide-rest. This was corrected as much as possible in the finishing draught by driving wedges under one or the other side of the plate until it was judged that the wire lay straight in the drum.

The punches used by the workmen were their private property, and not ground to any standard of taper.

Three punches examined; assigned value of taper, 0.2, or 1 in 5; values of three punches examined, 0.1936, —0.1488, —0.1420; —0.1488 from punch used for sixth draught; the others from punches used in fifth draught.

APPENDIX 44.

ORT SHOWING THE NATURE AND PROGRESS OF THE WORK DONE 'R THE ORDNANCE DEPARTMENT, U. S. ARMY, BY THE MIDVALE 'EEL COMPANY DURING THE FISCAL YEAR ENDING JUNE 30, 1885.

BY LIEUT. F. E. HOBBS, ORDNANCE DEPARTMENT.

MIDVALE STEEL WORKS,
Philadelphia, Pa., August 15, 1885.

CHIEF OF ORDNANCE, U. S. ARMY,
Washington, D. C.:

IR: Complying with your instructions, I have the honor to submit
following report, showing the nature and progress of the work done
the Ordnance Department by the Midvale Steel Company during
fiscal year ending June 30, 1885.*

uring the time specified the Midvale Steel Company continued work
er the following contracts with the Department, viz:

) Rolled and hammered hoops for an 8-inch steel breech-loading
.

) Forgings for the breech mechanism of 12-inch, 10-inch, and 8-inch
ch-loading rifles, and casting for 10-inch rifle.

) Rolled hoops for a 12-inch breech-loading rifle.

) Rings, forgings, and castings for a 10-inch steel wire-wound
ch-loading rifle.

nd also undertook to execute the following contracts or orders for
l for gun construction, viz:

) Forging for breech-bushing for 12-inch cast-iron rifle.

) Forgings for fifty steel tubes, breech cups, and muzzle collars for
h converted rifles.

) Forgings for the parts of twenty-five 3.2-inch steel breech-loading
. guns.

) Tube, jacket, and trunnion hoop for an 8-inch steel breech-load-
rifle.

) Experimental trunnion hoop for an 8-inch steel breech-loading
.

0) Forgings and castings for steel shells.

1) Forging for disk.

t this date those numbered 1, 2, 3, 4, 5, 10, and 11 are completed,
those (numbered 6, 7, 8, and 9 are still in hand.

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*early all information relative to manufacture is omitted in this report, as the
ale Steel Company desire that all details of this nature shall be considered con-
tial, and for the use of the Department only.

ROLLED AND HAMMERED HOOPS FOR AN 8-INCH STEEL BREECH-LOADING RIFLE.

The dimensions of these hoops, with some account of their manufacture, and summaries of the results of the tests of specimens taken from them, were given in report for the fiscal year ending June 30, 1884. There remained after the date of that report but little to be done to complete this contract. The results of the tests made at Watertown Arsenal, other than those given in the report for 1884, will be found below:

Result of tensile tests of tangential specimens from rolled steel hoops for 8-inch breech-loading rifle.

Specimen. From hoop marked—	Specimen. No.	Position.	Dimensions. Length.	Dimensions. Diameter.	Sectional area.	Elastic limit per square inch of original section.	Elongation per inch under strain at elastic limit.	Tensile strength per square inch of original section.	Elongation per inch after rupture.	Reduction in area after rupture.
			In.			Pounds.	Inch.	Pounds.	Inch.	Pr. cent.
A_8	1	Inside	6	0.564 of an inch.	0.25 of a square inch.	48,000	.001416	85,920	.138	54.
A_8	2	Outside	6			51,000	.001533	90,240	.137	57.
A_8	3	Inside	3			60,000	.001866	98,920	.200	53.
A_8	4	Outside	3			60,000	.001866	100,400	.177	47.
A_{11} *	7	Inside	6			55,000	.001833	103,240	.1667	41.
A_{11}	8	Outside	6			55,000	.001783	105,440	.1567	39.
A_{11}	9	Middle	6			57,000	.001867	104,320	.1317	32.

* Made to replace hoop A_{11}, which had been rejected.

FORGINGS FOR THE BREECH MECHANISM OF 12-INCH, 10-INCH, AND 8 INCH BREECH-LOADING RIFLES, AND CASTING FOR 10-INCH RIFLE.

The rough-finished dimensions of these forgings, the required physical qualities of the metal, and summaries of the results of the tests of certain specimens, were given in report for 1884. There is no special remark to be made on the manufacture of these forgings other than that in piercing the 8-inch spindle for the vent cracks were discovered which necessitated its condemnation.

The results obtained in tensile tests of specimens from the 8-inch breech-block and the sleeve casting are given below.

Results of tensile tests of tangential specimens from forging for 8-inch breech block.

No. of specimen.	Dimensions. Length.	Dimensions. Diameter.	Sectional area.	Elastic limit per square inch of original section.	Elongation per inch under strain at elastic limit.	Tensile strength per square inch of original section.	Elongation per inch after rupture.	Reduction in area after rupture.
	In.			Pounds.	Inch.	Pounds.	Inch.	Per cent.
3	3	0.564 of an inch.	0.25 of a square inch.	48,000	.001667	94,000	.2067	44.6
4	3			49,000	.001700	95,200	.1933	44.6

Results of tensile tests of tangential specimens from sleeve-casting for 10-inch cast-iron wire-wound rifle.

No. of specimen.	Dimensions.		Sectional area.	Elastic limit per square inch of original section.	Elongation per inch under strain at elastic limit.	Tensile strength per square inch of original section.	Elongation per inch after rupture.	Reduction in area after rupture.	Specific gravity.	
	Length.	Diameter.								
	In.			*Pounds.*	*Inch.*	*Pounds.*	*Inch.*	*Per cent.*		
1	3	0.564 of an inch.	0.25 of a square inch.	53,000	.001767	96,000	.1933	36.4	7.8365	20.14
2	3			55,000	.001567	98,480	.933	11.8	....	....
3	3			49,000	.001500	93,600	.1500	18.3	....	....

ROLLED HOOPS FOR 12-INCH BREECH-LOADING RIFLE.

The rough-finished dimensions of these hoops, specified in the contract, were as follows:

Number of hoops.	Interior. diameter.	Exterior diameter.	Length.
	Inches.	*Inches.*	*Inches.*
13	38[illegible]	46$\frac{3}{16}$	12¼
1	38[illegible]	46$\frac{7}{16}$	11¼
1	38[illegible]	47$\frac{3}{16}$	12¼
9	45[illegible]	53⅛	12¼
1	45[illegible]	53⅛	12
2	45[illegible]	52⅝	12¼

The physical qualities of the metal to be: Elastic limit, 51,000 to 60,000 pounds per square inch; tensile strength, 96,000 to 105,000 pounds per square inch; elongation after rupture; over 15 per cent., as determined by the test of specimens 6 inches long between shoulders and 0.564 of an inch in diameter. The treatment to be that already prescribed by the Department for steel for ordnance purpose, *i. e.*, oil tempering and subsequent partial annealing.

The company experienced some difficulty in the manufacture of these hoops, and after having made a number of them, found that they had overestimated the rough-finished length which could be obtained using the rolls at the height they had determined upon as sufficient. As the work had by that time proceeded so far that the condemnation of all these hoops would have entailed serious financial loss on the company, they requested the Department, if possible, to sochange the plan of hooping this gun as to enable them to use at least a part of these hoops, and at the same time they increased the height of the rolls, so that the remainder of the hoops to be subsequently manufactured would certainly rough-finish to the required length.

Under date of October 25, 1884, you were pleased, in view of the stated facts of the case, and desiring to accede to the company's request as far as could be done without injury to the plan of construction, to so modify the adopted plan of hooping the gun as to necessitate the condemnation of but 4 of the 23 hoops already manufactured and specified the following modified rough-finished dimensions for the hoops:

Number of hoops.	Interior diameter.	Exterior diameter.	Length.
10	38[illegible]	46[illegible]	12[illegible]
2	38[illegible]	46[illegible]	11[illegible]
1	38[illegible]	46[illegible]	11[illegible]
1	38[illegible]	46[illegible]	10[illegible]
1	38[illegible]	47[illegible]	12[illegible]
7	45[illegible]	53[illegible]	12[illegible]
1	45[illegible]	53[illegible]	12
1	45[illegible]	53[illegible]	11[illegible]
1	45[illegible]	53[illegible]	10[illegible]
2	45[illegible]	52[illegible]	12[illegible]

Some difficulty was also experienced in obtaining the required physical qualities of the metal, and retempering and reannealing were frequently resorted to.

The probable cause of this difficulty was a less thorough working of the metal than had been obtained in the case of the 8-inch rifle hoops, for being the first of such very large, thick, and heavy hoops manufactured by the company, they were handled cautiously both under the hammer and at the rolls, and were heated frequently and to quite a high temperature.

With the plant and facilities for manufacture at hand, and considering the size of the hoops, the final result obtained is believed to be very fair, if not quite up to the excellent results obtained in the 8-inch hoops referred to above; the hoops were manufactured in the same manner as those for the 12-inch muzzle-loading rifled mortar and the rolled 8-inch steel breech-loading rifle referred to in report for 1884. Summaries of the results of tests made at Watertown Arsenal of specimens from these hoops are given below:

Results of tensile tests of tangential specimens from rolled steel hoops for 12-inch breech-loading rifle.

[Length of specimen, 6 inches; sectional area, 0.25 of a square inch.]

Number of hoop.	Number of specimen.	Position of specimen.	Elastic limit per square inch of original section.	Elongation per inch under strain at elastic limit.	Tensile strength per square inch of original section.	Elongation per inch after rupture.	Reduction in area after rupture.	Specific gravity.	Hardness.
			Pounds.	*Inch.*	*Pounds.*	*Inch.*	*Per cent.*		
A_{11}†	1	Inside	59,000	.001933	107,040	.135	36.4	[illegible]	[illegible]
A_{11}†	2	Outside	61,000	.002133	109,280	.145	36.4	-------	----
A_{11}†	3	Inside	60,000	.001967	107,200	.150	39.2	-------	----
A_{11}†	4	Outside	59,000	.001883	107,120	.150	36.4	-------	----
A_{11}‡	5	Inside	53,000	.001767	107,840	.105	24.6	[illegible]	[illegible]
A_{11}‡	6	Outside	53,000	.001767	107,240	.1117	24.6	-------	----
A_{11}‡	7	Middle	47,000	.001650	103,340	.1117	27.6	-------	----
A_{11}§	8	Inside	43,000	.001350	99,920	.1467	41.9	[illegible]	[illegible]
A_{11}§	9	Outside	47,000	.001400	98,880	.1333	41.9	-------	----
A_{11}§	10	Middle	49,000	.001567	102,560	.1333	36.4	-------	----
A_{11}	11	Inside	52,000	.001783	105,920	.1233	33.5	-------	----
A_{11}	12	Outside	59,000	.002033	112,000	.1133	33.5	-------	----
A_{11}	13	Middle	56,000	.001833	103,920	.1383	41.9	-------	----

† Accepted on these tests, but found afterwards to be scant of the required dimensions—a new hoop made to replace it.

‡ New hoop A_{11} not accepted on these tests.

§ Not accepted on these tests.

Results of tensile tests of tangential specimens, &c.—Continued.

Number of specimen.	Position of specimen.	Elastic limit per square inch of original section.	Elongation per inch under strain at elastic limit.	Tensile strength per square inch of original section.	Elongation per inch after rupture.	Reduction in area after rupture.	Specific gravity.	Hardness.
		Pounds.	*Inch.*	*Pounds.*	*Inch.*	*Per cent.*		
1	Middle	57,000	.002050	107,600	.1417	36.4	7.8577	23.03
2	....do	55,000	.001950	104,480	.1483	36.4		
3	....do	55,000	.001900	106,400	.1267	33.5		
4	....do	57,000	.001900	104,560	.1467	39.2		
5	Inside	65,000	.002417	111,800	.1333	41.9		
6	Outside	57,000	.002233	106,240	.1483	36.4		
1	Middle	54,000	.001750	105,600	.1383	30.6	7.8588	22.87
2	....do	53,000	.001717	104,200	.1617	33.5		
3	....do	50,000	.001700	101,200	.1700	36.4		
4	....do	49,000	.001633	101,280	.1517	33.5		
5	Inside	52,000	.001867	104,400	.1433	33.5		
6	Outside	53,000	.002100	102,000	.1383	36.4		
1	Inside	34,000	.001333	88,600	.1333	39.2	7.8575	14.9
2	Outside	37,000	.001367	88,000	.205	33.5		
3	Inside	55,000	.002100	101,660	.125	33.5	7.8632	19.81
4	Outside	55,000	.001883	107,160	.1283	30.6		
5	Middle	53,000	.001883	102,400	.1367	33.5		
1	Middle	48,000	.001617	100,240	.1567	39.2	7.8543	19.81
2	....do	49,000	.001617	101,000	.1567	39.2		
3	....do	50,000	.001717	102,280	.1500	36.4		
4	....do	49,000	.001700	100,000	.1617	39.2	7.8581	20.36
5	Inside	48,000	.001683	102,280	.1667	33.5		
6	Outside	49,000	.001783	100,640	.1483	36.4		
7	Inside	52,000	.001767	107,920	.1267	27.6	7.8515	22.39
8	Outside	53,000	.001917	106,000	.1317	30.6		
9	Middle	50,000	.001700	106,160	.155	30.6		
10	....do	49,000	.001683	105,600	.1433	30.6		
1	Middle	54,000	.001867	109,280	.1217	30.6	7.8568	22.64
2	....do	51,000	.001800	101,160	.1483	36.4		
3	... do	55,000	.001983	108,200	.1283	30.6		
4	....do	48,000	.001667	98,080	.1483	41.9		
5	Inside	64,000	.002350	114,600	.1017	27.6		
6	Outside	54,000	.001950	102,000	.145	41.9		
1	Inside	59,000	.001983	109,560	.1533	39.2		
2	Outside	61,000	.002050	109,160	.1600	41.9		
3	Inside	58,000	.001900	108,200	.1550	39.2		
4	Outside	60,000	.001950	108,650	.1533	41.9		
5	Middle	61,000	.002133	112,000	.1333	36.4		
6	....do	59,000	.001967	109,440	.145	39.2		
1	Inside	53,000	.001867	102,280	.1417	41.9	7.8511	22.14
2	Outside	54,000	.001783	104,080	.1500	36.4		
3	Inside	53,000	.001850	102,200	.1433	39.2		
4	Outside	53,000	.001783	102,240	.1683	39.2		
1	Middle	54,000	.001767	101,200	.160	39.2	7.8564	21.64
2	....do	55,000	.001850	104,400	.1333	33.5		
3	....do	53,000	.001733	102,480	.145	36.4		
4	...do	53,000	.001717	101,840	.1483	36.4		
5	Inside	58,000	.002183	107,000	.1483	33.5		
6	Outside	57,000	.002117	106,000	.1583	33.5		
1	Middle	54,000	.001750	104,320	.1383	36.4	7.8532	21.52
2	....do	53,000	.001717	104,000	.1267	36.4		
3	....do	54,000	.001800	106,760	.1400	33.5		
4	....do	52,000	.001667	105,280	.1433	36.4		
5	Inside	51,000	.001950	100,160	.1383	39.2		
6	Outside	53,000	.001967	105,120	.1517	33.5		

ot accepted on these results; retempered and annealed.
ot accepted on these tests.

Results of compression tests of tangential specimens from rolled steel hoops for 12-inch breech-loading rifle.

Specimen.		Position.	Dimensions.		Elastic limit per square inch of original section.	Compression per inch under strain at elastic limit.	Ultimate strength per square inch of original section.
From hoop marked—	Number.		Length.	Diameter.			
			Inch.	*Inch.*	*Pounds.*	*Inch.*	*Pounds.*
A$_6$....	7	Middle...	12	1.129	58,000	.001980	65,250
Bx...	7	..do......	12	1.129	54,000	.001720	65,460
Bx....	8	Inside	12	1.129	54,000	.001720	63,350
B$_{11}$....	7	Outside...	12	1.129	54,000	.001870	63,200

Sectional area, 1 square inch.

Results of compression tests of radial specimens from rolled hoops for 12-inch breech-loading rifles.

Specimen.		Length.	Diameter.	Ultimate strength per square inch of original section.
From hoop marked—	Number.			
		Inch.	*Inch.*	
A$_6$...	8	4	0.565	73,020
Bx....	9	4	0.505	69,930
Bx....	10	4	0.505	66,270
B$_{11}$....	9	4	0.505	68,450

Sectional area, 0.2 of a square inch.

RINGS, FORGINGS, AND CASTING FOR 10-INCH STEEL WIRE-WOUND BREECH-LOADING RIFLE.

Under this contract the company were required to deliver 12 rings, breech-block, 1 spindle, 1 lever, and 1 cylinder (sleeve casting), the rough-finished dimensions being as follows:

Dimensions of hoops.

No. of hoops.	Interior diameter.	Exterior diameter.	Length.	Rolled or hammered.
	Inches.	*Inches.*	*Inches.*	
1	23	31½	1 3/16	Rolled.
1	22½	29½	6 3/16	Do.
1	28	35	8 3/16	Do.
1	16½	25	1 3/16	Hammered.
1	16½	25	5¼	Do.
1	18⅜	23 1/16	9¼	Do.
1	12 3/16	16½	1½	Do.
1	12 3/16	16½	5¼	Do.
1	22½	36 1/16	5¼	Do.
1	22 11/16	36 5/16	1½	Do.
1	30½	36 1/16	1 3/16	Do.
1	24	28½ 30 11/16	4 13/16	Do.

Dimensions of other forgings and casting.

Nature of piece.	Interior diameter.	Exterior diameter.	Length.
	Inches.	*Inches.*	*Inches.*
ler casting	30.25	33.5	34.75
h-block	2.5	14.25	20
le		12.25 4.25	3.75 24
		13.5	1.125

Physical qualities of the metal.

Nature of piece.	Elastic limit.	Tensile strength.	Elongation after rupture.
	56,000 pounds per square inch; variation allowed ± 4,500 pounds per square inch.	100,800 pounds per square inch; variation allowed ± 4,500 pounds per square inch.	Over 15 per cent.
h-block and spindle	50,000 to 56,000 pounds per square inch.	108,000 to 112,000 pounds per square inch.	Over 12 per cent.
		80,640 pounds per square inch.	Over 20 per cent.
casting	40,000 to 45,000 pounds per square inch.	90,000 to 108,000 pounds per square inch.	At least 10 per cent.

special comment can be made on the manufacture of these parts 10-inch steel wire-wound rifle. Much difficulty was experienced etting satisfactory tests from one of the rolled hoops and also in ining a satisfactory sleeve casting, but otherwise the work prosed rapidly, satisfactorily, and without incident. Summaries of the lts obtained from the tests of specimens from these forgings are n below:

ts of tensile tests of tangential specimens from hoops for 10-inch steel wire-wound breech-loading rifle.

Number of specimen.	Position of specimen.	Length.	Elastic limit per square inch of original section.	Elongation per inch under strain at elastic limit.	Tensile strength per square inch of original section.	Elongation per inch after rupture.	Reduction in area after rupture.	Specific gravity.	Hardness.
		In.	*Pounds.*	*Inch.*	*Pounds.*	*Inch.*	*Per cent.*		
1	Middle	6	55,000	.001800	101,120	.165	41.9	7.8571	22.53
2	Middle	6	53,000	.001733	101,840	.1467	36.4		
3	Middle	6	56,000	.001867	103,200	.155	39.2		
1	Middle*	6	49,000	.001617	97,300	.1533	39.2	7.8568	20.03
2	Middle*	6	47,000	.001533	95,840	.1633	36.4		
3	Middle*	6	48,000	.001600	97,040	.1733	39.2		
4	Middle†	6	45,000	.001683	100,280	.1483	30.6	7.8508	20.47
1	Middle†	6	49,000	.001567	99,880	.145	30.6	7.8557	20.25
2	Middle†	6	45,000	.001467	95,200	.1517	41.9		
3	Middle†	6	48,000	.001583	100,000	.1500	36.4		
7	Inside*	6	45,000	.001417	100,480	.1467	30.6		
8	Outside*	6	49,000	.001683	105,880	.1217	27.6		
9	Middle*	6	47,000	.001583	101,560	.12	27.6		
10	Inside	6	61,000	.002083	114,000	.125	36.4	7.8527	22.02
11	Outside	6	65,000	.002200	117,680	.1133	30.6		
12	Middle	6	55,000	.001800	108,000	.1117	33.5		

ot accepted on these tests; retreated.

† Not accepted; another hoop made to replace it.

Results of tensile tests of tangential specimens from sleeve casting for 10-inch steel wire-*wound breech-loading rifle.*

[Length of specimen, 3 inches. Sectional area, 0.25 of a square inch.]

No. of specimen.	Elastic limit per square inch of original section.	Elongation per inch under strain at elastic limit.	Tensile strength per square inch of original section.	Elongation per inch after rupture.	Reduction in area after rupture.	Specific gravity.	Hardness.
	Pounds.	*Inch.*	*Pounds.*	*Inch.*	*Per cent.*		
1	55,000	.002000	104,120	.1367	24.6	7.8411	15.83
2	57,000	.001900	102,000	.1533	27.6	....	....
3	56,000	.001867	101,720	.1567	33.5	....	....

FORGING FOR BREECH BUSHING FOR 12-INCH CAST-IRON RIFLE.

This forging was required to be 24.25 inches exterior diameter, 14.75 inches interior diameter, 24 inches long, rough-finished dimensions. It was forged and treated in the same manner as a gun-hoop. Specimens cut from one end showed the following physical qualities:

No. of specimen.	Length of specimen.	Elastic limit per square inch of original section.	Elongation per inch under strain at elastic limit.	Tensile strength per square inch of original section.	Elongation per inch after rupture.	Reduction in area after rupture.	Specific gravity.	Hardness.
	In.	*Pounds.*	*Inches.*	*Pounds.*	*Inches.*	*Per cent.*		
1	3	55,000	.001767	102,800	.1867	36.4	7.8558	21.89
2	3	57,000	.002167	102,480	.1933	39.2	....	....

FORGINGS FOR FIFTY TUBES, BREECH CUPS, AND MUZZLE COLLARS FOR 8-INCH CONVERTED RIFLES.

These forgings are required of the following dimensions:

Nature of piece.	Exterior diameter.	Interior diameter.	Length.	Remarks.
	Inches.	*Inches.*	*Inches.*	
Tube	13.375	7.625	124	Rough finished.
Breech cup	8.5	....	7	Rough forging.
Muzzle collar	13.75	11.25	6.5	Rough finished.

The mean physical qualities of the tube and breech cup to be: Elastic limit, 38,000 pounds per square inch; tensile strength, 80,000 pounds per square inch; elongation after rupture, 22 to 26 per cent.; reduction of area, 20 per cent.; but the results of no one specimen to be below elastic limit, 35,000 pounds per square inch; tensile strength, 75,000 pounds per square inch; elongation after rupture, 20 per cent.

The forgings for the tube were required to be of open-hearth steel, from ingots weighing about twice as much, and having a sectional area about four times as great as the solid forging, and to be from the lower part of the ingots. The rough finished tubes and the rough forgings for breech cups to be oil tempered and afterwards annealed. The tube rgings were made from ingots 25 inches square in cross-section by bout 50 inches high, weighing about 11,000 pounds each. The forgngs were tested by the Midvale Steel Company, and then sent to nother firm to be rough turned and bored, the company not having e facilities for this kind of work; on their return they were oil temered and annealed, and the required test specimens cut from the ends. he treatment required, oil tempering and annealing, differs from the eatment to which the first tube manufactured by this company was bjected, viz, simple annealing; the specifications under the adversement asking for bids for these tubes allowed the manufacturers to ate the price for either oil tempered and annealed or simple anealed forgings, having the physical qualities specified.

This company, to whom the contract was awarded, bid only on oil empered and annealed forgings, believing that such treatment would ive them a better control over the metal. Up to this date fifty-six ubes have been forged, of which twenty-seven have been accepted as physical qualities and six have been rejected; the rejections have een principally on account of local defects at the ends of the tubes. hree specimens are tested from each end of each tube, so the total numer of tests made is quite large. Summaries of the results obtained om several of both the accepted and rejected tubes are given below s examples.

esults of tensile tests of tangential specimens from ends of tubes for 8-inch converted rifles.

[Length of specimen, 3 inches; sectional area, 0.25 of a square inch.]

Breech or muzzle.	Number of specimen.	Position of specimen.	Elastic limit per square inch of original section.	Elongation per inch under strain at elastic limit.	Tensile strength per square inch of original section.	Elongation per inch after rupture.	Reduction in area after rupture.	Specific gravity.	Hardness.
			Pounds.	*Inch.*	*Pounds.*	*Inch.*	*Per cent.*		
Breech	1	Inside	44,000	.001400	83,800	.1300	18.3	7.8528	13.65
....do	2	Outside	41,000	.002100	82,600	.1167	15.0	....	......
....do	3	Middle	43,000	.001333	84,320	.2333	41.9	....	......
Muzzle	1	Inside	45,000	.001133	88,240	.2367	44.6	7.8542	14.98
....do	2	Outside	45,000	.001367	88,000	.240	49.7	....	......
....do	3	Middle	47,000	.001467	87,200	.2167	47.2	....	......
* Breech	1	Inside	40,000	.001333	75,600	.1133	21.4	7.8607	11.18
* ....do	2	Outside	43,000	.001400	82,080	.2400	49.7	....	......
* ....do	3	Middle	40,000	.001233	82,000	.2067	27.6	....	......
* Muzzle	1	Inside	47,000	.001533	86,000	.2533	41.9	7.8566	14.40
* ....do	2	Outside	42,000	.001400	81,040	.2233	49.7	....	......
* ....do	3	Middle	45,000	.001400	82,120	.2233	52.2	....	......
* Breech	4	Inside	40,000	.001267	80,160	.170	39.2	....	......
* ....do	5	....do	41,000	.001367	80,080	.170	44.6	....	......
* ....do	6	Outside	39,000	.001233	77,920	.2367	52.2	....	......
† ....do	1	Inside	43,000	.001333	81,440	.2233	49.7	7.8539	13.40
† ....do	2	Outside	45,000	.001533	84,680	.220	54.6	....	......
† ....do	3	Middle	41,000	.001267	79,800	.260	54.6	....	......
† Muzzle	1	Inside	42,000	.001333	81,660	.2333	49.7	7.8525	12.48
† ....do	2	Outside	40,000	.001100	80,600	.220	49.7	....	......
† ....do	3	Middle	45,000	.001300	84,160	.2433	44.6	....	......
* Breech	1	Inside	44,000	.001500	82,000	.2100	47.2	7.8553	12.84
* do	2	Outside	41,000	.001200	80,600	.2100	54.6	....	......
* ....do	3	Middle	39,000	.001200	79,280	.2233	49.7	....	......
* Muzzle	1	Inside	41,000	.001300	80,160	.1800	41.9	7.8352	12.48
* ....do	2	Outside	41,000	.001167	78,880	.2267	52.2	....	......
* ....do	3	Middle	33,000	.001133	59,680	.0467	11.8	....	......
* ....do	4	Inside	37,000	.001167	67,200	.0533	11.8	....	......
* ....do	5	Outside	35,000	.001133	67,000	.070	11.8	....	......
* ....do	6	Middle	32,000	.001100	58,560	.060	11.8	....	......
* ....do	7	....do	39,000	.001267	80,200	.2267	47.2	....	......

* Not accepted on these tests. † Accepted on these tests.

Results of tensile tests of tangential specimens from ends of tubes, &c.—**Continued.**

[Length of specimen, 3 inches; sectional area, 0.25 of a square inch.]

Number of tube.	Breech or muzzle.	Number of specimen.	Position of specimen.	Elastic limit per square inch of original section.	Elongation per inch under strain at elastic limit.	Tensile strength per square inch of original section.	Elongation per inch after rupture.	Reduction in area after rupture.	Specific gravity.	Hardness.
				Pounds.	*Inch.*	*Pounds.*	*Inch.*	*Per cent.*		
13*	Breech........	1	Inside.........	37,000	.001233	75,280	.2233	41.9	7.8584	[illegible]
13*	....do.........	2	Outside	40,000	.001433	78,840	.1467	21.4	....	......
13*	... do.........	3	Middle	37,000	.001400	75,720	.1967	33.5	....	......
13*	Muzzle........	1	Inside	44,000	.001400	83,320	.2667	49.7	7.8549	[illegible]
13*	....do.........	2	Outside	40,000	.001367	79,640	.2500	47.2	....	......
13*	....do	3	Middle	43,000	.001367	83,000	.2067	47.2	....	......
13*	Breech........	4	Inside	39,000	.001233	78,000	.2107	48.9	....	......
13*	....do.........	5	Outside	35,000	.001133	75,480	.2333	41.5	....	......
13*	....do.........	6	Middle	35,000	.001100	74,720	.1667	30.6	....	......
13*	....do.........	7	....do.........	35,000	.001067	74,400	.2667	47.2	....	......
20†	....do.........	1	Inside.	35,000	.001133	72,520	.230	52.2	7.8576	[illegible]
20†	....do.........	2	Outside	38,000	.001267	77,280	.230	49.7	....	......
20†	....do.........	3	Middle	37,000	.001267	75,000	.2667	47.2	....	......
20†	Muzzle........	1	Inside.........	44,000	.001467	81,360	.240	41.9	7.[illegible]	[illegible]
20†	....do.........	2	Outside	42,000	.001433	80,200	.1967	33.5	....	......
20†	... do.........	3	Middle	41,000	.001400	79,400	.2533	52.2	7.8545	[illegible]
22†	Breech........	1	Inside.........	38,000	.001167	74,640	.2633	47.2	....	......
22†	....do...	2	Outside	39,000	.001200	78,000	.2333	49.7	....	......
22†	... do.........	3	Middle	40,000	.001300	78,080	.2233	44.6	7.[illegible]	[illegible]
22†	Muzzle........	1	Inside	30,000	.001300	75,240	.2233	57.0	....	......
22†	... do.........	2	Outside	39,000	.001100	75,360	.2467	54.6	....	......
22†	....do.........	3	Middle	37,000	.001233	73,120	.240	61.5	....	......
24†	Breech........	1	Inside...	44,000	.001400	76,800	.260	59.3	7.[illegible]	[illegible]
24†	... do.........	2	Outside	41,000	.001400	80,480	.2667	53.2	....	......
24†	do	3	Middle	41,000	.001267	79,160	.2467	54.6	....	......
24†	Muzzle........	1	Inside.........	45,000	.001533	86,360	.2333	47.2	7.[illegible]	[illegible]
24†	... do.........	2	Outside	43,000	.001567	83,280	.250	47.2	....	......
24†	....do.........	3	Middle	41,000	.001367	82,440	.2367	49.7	....	......
28†	Breech........	1	Inside........	45,000	.001367	80,240	.240	52.2	7.[illegible]	[illegible]
28†	....do.........	2	Outside	40,000	.001233	82,000	.2267	49.7	....	......
28†	....do	3	Middle	43,000	.001267	82,000	.2233	49.7	....	......
28†	Muzzle........	1	Inside	46,000	.001367	83,960	.2067	52.2	7.[illegible]	[illegible]
28†	....do....... ..	2	Outside	44,000	.001367	84,560	.2533	52.2	....	......
28†	....do.........	3	Middle	43,000	.091400	84,200	.2467	49.7	....	......
31*	Breech........	1	Inside	35,000	.001033	72,240	.260	41.9	7.[illegible]	[illegible]
31*	....do.........	2	Outside	35,000	.001100	74,080	.2667	44.6	....	......
31*	... do.........	3	Middle	34,000	.001100	71,840	.2467	41.9	....	......
31*	Muzzle........	1	Inside...	42,000	.001433	81,480	.140	24.6	7.[illegible]	[illegible]
31*	....do.........	2	Outside	43,000	.001333	83,560	.160	32.5	....	......
31*	... do.........	3	Middle	40,000	.001433	76,720	.2267	41.9	....	......
31†	....do.........	4	Inside	41,000	.001367	76,720	.240	47.2	....	......
31†	....do.........	5	Outside	41,000	.001300	77,400	.230	47.2	....	......
31†	... do.........	6	Middle	39,000	.001367	76,000	.220	32.5	....	......
31†	....do.........	7	....do.........	39,000	.001333	75,680	.2133	47.2	....	......
34†	Breech........	1	Inside.........	39,000	.001233	73,880	.2367	44.6	7.[illegible]	[illegible]
34†	....do.........	2	Outside	41,000	.001267	78,840	.210	44.6	....	......
34†	... do.........	3	Middle.........	40,000	.001333	75,160	.2567	47.2	....	......
34†	Muzzle........	1	Inside	43,000	.001300	79,480	.2267	41.9	7.[illegible]	[illegible]
34†	....do.........	2	Outside	41,000	.001167	76,600	.260	49.7	....	......
34†	....do.........	3	Middle.........	40,000	.001300	78,600	.2367	44.6	....	......
43†	Breech........	1	Inside.........	40,000	.001267	74,800	.250	49.7	7.8571	[illegible]
43†	... do.........	2	Outside	40,000	.001400	76,040	.240	52.2	....	......
43†	do.........	3	Middle..	39,000	.001200	75,040	.290	54.6	....	......
43†	Muzzle........	1	Inside.........	37,000	.001333	78,440	.2333	36.2	7.[illegible]	[illegible]
43†	.. do.........	2	Outside	38,000	.001233	75,920	.2433	36.2	....	......
43†	....do.........	3	Middle.........	37,000	.001200	78,680	.2033	21.4	....	......

* Not accepted on these tests.

† Accepted on these tests.

muzzle collars were manufactured like gun hoops, except that orging they were not treated in oil, but caused to cool slowly; vere then tested by the Midvale Steel Company under the super- of an inspector, and, if satisfactory, then accepted and rough d.

following are some of the results of tests:*

Tensile strength per square inch of original section.	Elongation per inch after rupture.	Reduction in area after rupture.
Pounds.	*Inches.*	*Per cent.*
86, 355	.16	20. 75
84, 882	.17	23. 87
86 355	.215	36. 25
84, 991	.225	36. 64
83, 937	.21	31
88, 276	.185	34. 91
84, 083	.20	29. 72
85, 651	.21	29. 10
85, 219	.19	34
85, 787	.23	37. 52

NGS FOR THE PARTS OF TWENTY-FIVE 3.2-INCH STEEL BREECH-LOADING FIELD GUNS.

se parts consist of tube, jacket, sleeve, base ring, key ring, breech obturator stem, lever handle, carrier ring, gas-checking ring, nut, unnion hoop, of the following rough-finished dimensions:

Nature of piece.	Interior diameter.	Exterior diameter.	Length.	Remarks.
	Inches.	*Inches.*	*Inches.*	
	2. 75	6. 25	85. 5	
	5. 25	9. 875	28. 8	
g	3. 5	6. 625	4. 25	
	5. 125	6. 93	13. 7	
:	4. 875	6. 75	3. 25	
ing	4. 25	7	1. 6	With projection.
k ring	2. 5	3. 75	0 9	
		1. 5	1	
lock	0. 5	4. 75	6. 75	With projections.
n hoop	5. 125	9. 4	9. 1	With rim bases and trunnions.
r stem		4 1. 75 1. 125	0. 9 1. 6 6. 65	

forgings of open-hearth steel, oil tempered and afterward an- l, and to have the following physical qualities:

	Elastic limit, 42,000 pounds per square inch. Tensile strength, 88,000 pounds per square inch. Elongation after rupture, 20 per cent.	The results of the test of no one specimen to be below—	Elastic limit, 36,000 pounds per square inch. Tensile strength, 80,000 pounds per square inch. Elongation after rupture, 12 per cent.
leeve, breech base ring, other small gs.	Elastic limit, 50,000 pounds per square inch. Tensile strength, 95,000 pounds per square inch. Elongation after rupture, 18 per cent.	The results of the test of no one specimen to be below—	Elastic limit, 46,000 pounds per square inch. Tensile strength, 88,000 pounds per square inch. Elongation after rupture, 15 per cent.
a hoop	Elastic limit, 48,000 pounds per square inch. Tensile strength, 95,000 pounds per square inch. Elongation after rupture, 15 per cent.	The results of the test of no one specimen to be below—	Elastic limit, 43,000 pounds per square inch. Tensile strength, 85,000 pounds per square inch. Elongation after rupture, 12 per cent.

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* Length of specimen, 2 inches; sectional area, 0.2 of a square inch.

The forgings, with the exception of the tube and trunnion hoop, were made in the same manner as those for an experimental 3.2 inch steel breech-loading field gun, described in report for 1884. The tubes, like the other parts, were to be oil tempered and afterward annealed, instead of simply annealed as in the case of the experimental gun, this change being made with the expectation of obtaining more uniform metal of the desired physical qualities. The trunnion hoops are forgings instead of being castings, as for the experimental gun, this chang also being made in the expectation of obtaining better metal.

Up to the present time but few of these forgings have been complete and submitted for test by the Department; the work, however, is in forward state of completion. The results of the tests of such of thes forgings as have been completed are given below:

Results of tensile tests of tangential specimens from forgings for the parts of 3.2-inch st breech-loading field guns.

[Length of specimen, 2 inches: sectional area, 0.2 of a square inch.]

Nature of piece.	Number of piece.	Number of specimen.	Elastic limit per square inch of original section.	Elongation per inch under strain at elastic limit.	Tensile strength per square inch of original section.	Elongation per inch after rupture.	Reduction in area after rupture.	Specific gravity.
			Pounds.	*Inches.*	*Pounds.*	*Inches.*	*Per cent.*	
Jacket	1	1	52,000	.001600	99,100	.20	40.5	7.8695
Do	1	2	50,000	.001500	95,000	.165	24.0	
Do	2	1	60,000	.002500	106,000	.165	30.5	7.8656
Do	2	2	57,000	.001850	99,400	.185	43.5	
Do	*3	1	60,000	.002400	107,300	.130	13.2	7.8590
Do	*3	2	57,000	.002500	107,250	.150	23.9	
Do	*4	1	59,000	.001800	104,100	.105	13.5	7.8666
Do	*4	2	52,000	.001750	104,000	.180	17.0	
Do	*5	1	56,000	.001650	109,000	.195	37.1	7.8750
Do	*5	2	56,000	.002050	100,000	.135	20.5	
Do	6	1	48,000	.001400	94,450	.210	43.3	7.8593
Do	6	2	48,000	.001700	94,750	.215	46.2	
Do	*7	1	46,000	.001650	93,050	.215	43.3	7.8671
Do	*7	2	45,000	.001750	90,500	.235	30.7	
Do	*8	1	46,000	.001550	91,400	.245	37.1	7.8694
Do	*8	2	45,000	.001350	94,000	.175	27.4	
Do	*9	1	50,000	.001700	98,750	.175	37.1	7.8641
Do	*9	2	48,000	.001550	99,600	.125	5.7	
Sleeve	1	1	61,000	.002100	109,500	.205	40.3	7.8621
Do	5	1	56,000	.001950	106,500	.150	30.7	7.8627
Do	10	1	55,000	.001800	105,000	.185	34.0	7.8636
Do	15	1	59,000	.002000	110,000	.155	30.7	7.8655
Base ring	1	1	52,000	.001850	103,550	.19	30.7	7.8578
Do	5	1	57,000	.001900	110,500	.15	23.9	7.8667
Do	10	1	53,000	.001750	102,900	.17	34	7.8646
Do	15	1	57,000	.001900	109,000	.195	30.7	7.8623
Do	20	1	59,000	.002150	107,750	.165	34.0	7.8616
Do	25	1	47,000	.001500	102,900	.19	30.7	7.8672

* Not accepted on these tests.

of compression tests of tangential specimens from forgings for the parts of 3.2-inch steel breech-loading field guns.

[Length of specimen, 4.5 inches; sectional area, 0.5 of a square inch.]

Nature of piece.	Number of piece.	Number of specimen.	Elastic limit per square inch of original section.	Compression per inch under strain at elastic limit.	Tensile strength per square inch of original section.
			Pounds.	*Inch.*	*Pounds.*
Jacket	1	3	48,000	.001600	95,800
Do	2	3	54,000	.001850	100,100
Do	3	3	59,000	.001950	105,800
Do	4	3	58,000	.001650	104,000
Do	5	3	54,000	.001900	99,300
Do	6	3	50,000	.001500	95,200
Do	7	3	48,000	.001600	96,200
Do	8	3	42,000	.001300	89,000
Do	9	3	54,000	.002000	94,800
Base-ring	1	2	49,000	.001400	101,100
Do	5	2	57,000	.001800	108,480
Do	10	2	59,000	.001800	105,800
Do	15	2	59,000	.001800	106,840
Do	20	2	51,000	.001600	100,960
Do	25	2	50,000	.001500	95,900
Obturator stem	1	1	66,000	.001800	109,400
Do	5	1	60,000	.001750	110,900
Do	10	1	73,000	.002400	110,760
Do	15	1	57,000	.001800	104,480
Do	20	1	63,000	.002100	113,160
Do	25	1	65,000	.002300	112,160

, JACKET, AND TRUNNION HOOP FOR AN 8-INCH STEEL BREECH-LOADING RIFLE.

the 1st of November last, you forwarded to the Midvale Steel
pany a circular letter inclosing drawings giving the dimensions of
tubes, jackets, and trunnion hoops for 8-inch and 10-inch steel
h-loading rifles, asking the price per pound at which rough-finished
ngs of the dimensions given could be furnished, and what time
d be required to deliver one set of each; on the 15th of November
Midvale Steel Company, acknowledging receipt of this letter, in-
attention to the fact that they were engaged in adding to their
, and would shortly be able to furnish all the parts of an 8-inch
rifle, and were very desirous at some future date of attempting
anufacture, if the Department would furnish drawings of the parts
ed. In forwarding this letter to the Department especial attention
nvited to the fact that with the proposed addition to the plant, which
d enable the Midvale Steel Company to manufacture the forgings
ll the parts of a high-power 8-inch steel rifle, the Department would
le to fabricate such guns in which all the parts would be of home
uction (for the Midvale Steel Company had already produced excel-
hoops for a gun of this caliber, the tube, jacket, and trunnion
s for which were furnished by Sir Joseph Whitworth & Co.); that,
ccessful, a step could be made toward the production in this coun-
f guns of the larger calibers to be used in our fortifications; that
xperience gained would be of value in connection with many ques-
of detail arising in work of making still larger forgings, and that
roduction of 8-inch steel rifles would soon become a matter of cur-

rent fabrication, for which the Department could depend on home products exclusively, and the way would be clear to enter upon the larger field of study and experiment which the production of the heavier calibers would require. On the 2d of April proposals were invited, by advertisement, for furnishing the three forgings enumerated above for an 8-inch gun of open-hearth steel of American production, and the contract was awarded to the Midvale Steel Company on April 20.

The forgings are of the following rough-finished dimensions:

Nature of piece.	Interior diameter.	Exterior diameter.	Length.	Remarks.
	Inches.	*Inches.*	*Inches.*	
Tube	7.25	15.5 16.25 14.0	264	
Jacket............	10 14.625	23.875 24.6	110	
Trunnion hoop..	23.25	31.25	13.75	With rimbases and trunnions.

and the metal is required to have the following physical qualities:

		But the results of the tests of no one of the specimens to be below—
Tube	Elastic limit, 48,000 pounds per square inch.	Elastic limit, 45,000 pounds per square inch.
	Tensile strength, 90,000 pounds per square inch.	Tensile strength, 82,000 pounds per square inch.
	Elongation after rupture, 21 per cent.	Elongation after rupture, 18 per cent.
Jacket..........	Elastic limit, 50,000 pounds per square inch.	Elastic limit, 46,000 pounds per square inch.
	Tensile strength, 98,000 pounds per square inch.	Tensile strength, 88,000 pounds per square inch.
	Elongation after rupture, 19 per cent.	Elongation after rupture, 17 per cent.
Trunnion ring.	Elastic limit, 45,000 pounds per square inch.	Elastic limit, 42,000 pounds per square inch.
	Tensile strength, 95,000 pounds per square inch.	Tensile strength, 88,000 pounds per square inch.
	Elongation after rupture, 15 per cent.	Elongation after rupture, 13 per cent.

The tube and jacket were to be forged from ingots weighing about twice as much, and having a sectional area from three to four times as great, as the solid forging, and to be from the lower part of the ingots.

At the present time the tube and jacket have been forged, and the tube is being rough finished. The tensile tests of specimens taken from the ends of the tube forging show that its qualities are good. Tests from the jacket have not been quite so satisfactory.

No work has been done on the trunnion hoop.

EXPERIMENTAL TRUNNION FOR 8-INCH STEEL BREECH-LOADING RIFLE.

This experimental forging is to be delivered in the rough forged state excepting that it will be cored, and it is, after acceptance as to physical qualities on the regular tensile tests of the metal, to be thoroughly and ustively tested both by machine tests of specimens and by shrink- It is required to possess the same physical qualities as the trunn- ioop to be delivered with the 8-inch tube and jacket. It has at time been forged, and is ready for treatment.

FORGINGS AND CASTINGS FOR STEEL SHELLS.

ese shells, six in number, to be used in experiments with nitro- rine, were made as follows: One forged and one cast projectile made from each of three kinds of metal, and after rough finishing oil tempered. The results of the tests of the metal are as follows:

Specimens.	Tensile strength per square inch of original section.	Elongation per inch after rupture.	Reduction in area after rupture.
	Pounds.	*Inch.*	*Per cent.*
From forged shells*..	164,845	.035	0
	181,802	.045	0
	197,708	.05	5.5
From cast shells*....	106,808	0	0
	130,101	0	0
	152,826	.01	0.39

*Length of specimen, 2 inches. Sectional area, 0.2 of a square inch.

is hoped that the results of the firing with these shells will give valuable information as to the best metal to be used for steel pro- es.

ONE DISK.

is disk, to be used in making some addition to the 8-inch Yates gun, forged from an ingot of a heat of ordnance metal, by upsetting rounding, and treated to obtain a tensile strength of about 85,000 ds and an elastic limit of about 36,000 pounds.

EXPERIMENTS.

To determine the condition of the metal before treatment, speci- s were taken from 12-inch rifle hoop A 13, and tested at Watertown nal. The results are:

Number of specimen.*	Position of specimen.	Elastic limit per square inch of original section.	Elongation per inch under strain at elastic limit.	Tensile strength per square inch of original section.	Elongation per inch after rupture.	Reduction in area after rupture.	Specific gravity.	Hardness.
1	Inside ...	34,000	.001333	83600	.1833	30.2	7.8575	14.9
2	Outside...	37,000	.001367	88000	.205	33.5	....	......

*Length of specimen, 6 inches. Sectional area, 0.25 of a square inch.

comparison of these results with those obtained in the tests of spec- s taken after oil tempering and annealing for the acceptance of the will show the result of the treatment.

(2) The question having been raised whether heating hoops or other parts of a built-up gun composed of oil-tempered and annealed steel would not injure the metal, some pieces of 12-inch rifle hoop Bx, large enough to furnish test specimens, were heated very slowly in hot air to about 520° F., and held at that temperature for a short time. The pieces were taken in close proximity to each other, and one inside and one outside specimen were heated together. Two of these after heating were buried in powdered lime so that they should cool very slowly, and the other two were allowed to cool in air, that is, about as rapidly as a part of a gun in assembling would cool. The specimens turned from the pieces gave the following results:

Number of specimen.*	Position of specimen.	Elastic limit per square inch of original section.	Elongation per inch under strain at elastic limit.	Tensile strength per square inch of original section.	Elongation per inch after rupture.	Reduction in area after rupture.
		Pounds.	*Inch.*	*Pounds.*	*Inch.*	*Pr. cent.*
11	Inside	52, 000	. 001750	100, 280	. 165	39. 2
12	Outside ...	54, 000	. 001717	104, 760	. 1367	36. 4
13	Inside	48, 000	. 001550	96, 800	. 1617	41. 9
14	Outside ...	53, 000	. 001867	103, 040	. 1517	39. 2

* Length of specimen, 6 inches. Sectional area, 0.25 of a square inch.

A comparison of these results with those obtained in the tests of the ordinary specimens from this hoop shows how little, if any, falling off took place on account of the heating. The chemical analysis of this metal was about that which had been shown by experiment to be the most easily affected by heating within the range suitable for ordnance purposes, and seemed to show that the mere heating of the several parts of a gun up to 500° or 600° F. (about what is required for shrinkage purposes), does not materially affect the metal.

(3) In July last, in compliance with your instructions, an experiment was made to determine the effect of pouring molten cast iron about a piece of oil-tempered steel. The metal selected was from the muzzle end of a tube for 8-inch converted rifles which had been rejected on account of poor tests from the breech end, a piece 15 inches long being cut from the muzzle end for the purpose.

A light finishing cut, about 2 inches in length, was taken on the bore of this piece at the end from which test specimens had been taken. As no accurate calipers for making fine measurements were at hand, a gauge rod was made to accurately fit this finished bore, measurements being taken at two scored diameters at right angles to each other. As it was desired that the expansion of this piece of tube due to the heating of the molten cast iron should be at least 0.02 inch on the diameter, another gauge rod was made 0.02 inch longer than the first one, to be used to determine when the piece of tube with the molten cast iron about it had expanded that amount.

The weight of cast iron to be used was determined from a consideration of the specific heats of the two metals, the weight of the piece of tube, and the melting point of cast iron, with a view to obtaining a temperature of not over 600° F. in the steel; of course the surface of contact in the steel was liable to be heated to a much higher temperature than 600° F., but it was hoped by removing the cast iron as soon as possible that the steel would not be raised to an excessively high peratare, and it was deemed best to make a calculation under a suption that would give a definite empirical rule that could be fol- ›d in any subsequent similar heating operation.

ıe amount of cast iron required was found to be about 120 pounds, ng a thickness of about 0.8 inch of metal about the piece of tube.

piece of tube was placed with its axis vertical in a green sand l, and was sunk about 1 inch in the lower flask of the mold to pre- ; the molten metal from running under the bottom and so up into bore.

wo flat bars of steel 0.25 inch thick were placed vertically in the mold ıe space to be filled with cast iron, and opposite to each other to itate stripping.

fter the piece of tube had been set in the mold and everything was ›adiness for pouring the cast iron, a final measurement was made ı the gauge rod at the scored diameters to determine that the meas- nents previously taken were correct. In pouring the mold was l in 0.5 minute; as soon as the mold was full, and as rapidly as ible thereafter, measurements were taken with the gauge rod 0.02 longer than the original diameter, the measurements alternating he scored diameters.

xpansion took place very suddenly two minutes after the mold was and was a little more than 0.02 inch; verifying insertions of the ;er gauge rod were immediately made on each scored diameter, the ; lifted, and the cast iron stripped from the tube. The piece of tube entirely free from the hot cast iron in 1.5 minutes after the expan- took place, and was allowed to cool in the open air. Measurements ›n twenty-five minutes after the tube was free from the cast iron ved that the tube had not up to that time contracted appreciably. metal was poured late one evening, and the tube was allowed to stand ' night; measurements on the scored diameters taken the following ning, about thirteen hours after the pouring, with the primitive ;e rod showed that the tube had, as nearly as could be determined, racted to its original diameter. Four specimens were then cut ı this end of the tube, their axes being about 1.5 inches from the end, from the top of the piece of tube as it stood in the mold. The tests of e specimens have shown that the physical qualities of the metal › not changed by the operation. Summary of the results of tests of imens before and after the pouring is as follows:

Number of specimen.*	Position of specimen.	Elastic limit per square inch of original section.	Elongation per inch under strain at elastic limit.	Tensile strength per square inch of original section.	Elongation per inch after rupture.	Reduction in area after rupture.	Specific gravity.	Hardness.
		Pounds.	*Inch.*	*Pounds.*	*Inch.*	*Pr. cent.*		
†1	Inside	46,000	.001467	81,320	.190	49.7	7.8562	12.25
†2	Outside	43,000	.001400	81,240	.2633	52.2		
†3	Middle	40,000	.001333	78,160	.2333	54.6		
‡4	Inside	45,000	.001267	78,480	.210	54.6		
‡5	Outside	43,000	.001300	80,240	.2433	44.6		
‡6	Middle	40,000	.001333	77,600	.190	52.2		
‡7	do	43,000	.001367	82,360	.2133	47.2		

* Length of specimen, 3 inches. Sectional area, 0.25 of a square inch.

† Before pouring.

‡ After pouring.

works before being shipped to this foundry where the finishing and fitting of the pieces is done. The tubes and muzzle-collars when received are rough finished interiorly and exteriorly; the breech-cups are rough, solid forgings. Up to this date the following steel forgings have been received, viz: 27 tubes, 50 muzzle-collars, and 37 breech-cups.

The following constitute the principal operations upon the tube, which is closed at the breech end by the breech-cup: 1, the tube is centered and bearings are turned for mounting it in the boring bed; 2, it is rough bored to a diameter about one-sixteenth of an inch under finished size, and at the same time is rough turned over the whole exterior length; 3, it is removed to a lathe and the seat for the breech-cup is finished and threaded; 4, the breech-cup is inserted and the tube then subjected to a water pressure of 120 pounds to test the tightness of the thread joint; 5, the tube is again placed in the bed and finished bored; 6, the tube is rifled; 7, it is finished, turned outside to fit the casing, and the muzzle-collar designated for it and is then tried in the casing; 8, before the final insertion the bore is "lapped" with a half round cylinder of lead, using emery and oil to grind and polish the surfaces of the grooves and lands.

To prepare the breech-cup for insertion it is first rough turned and faced at the ends; the cup proper is then cut and fine finished, and the surplus length at the base, varying from 0.875 to 1.5 inches, is faced on two sides to afford a hold for the wrench used for screwing the piece home; finally the thread is cut to suit that already made in the tube.

The operations upon the muzzle-collar comprise, 1, rough turning the exterior; 2, rough and fine finishing the interior; 3, cutting the thread and turning the exterior to fit a designated casing, in which operation the ring is mounted upon a mandrel.

The above is an outline of the principal operations required in the manufacture of the gun as far as the insertion and complete assemblage of the tube, casing, and muzzle-collar. When that is done it remains to insert the securing pin and vent bushing and stop the old vent. None of the tubes have as yet been assembled, but in connection with the above the progress of the work on the steel parts may be shown by the following:

Of the twenty-seven tubes received to date all have progressed as far as to include the stage of rough boring, 16 have the breech-cups inserted and are finished bored, 10 are rifled, 5 are finished exteriorly and fitted to casings and muzzle-collars, and 3 have been "lapped" and polished in the bore.

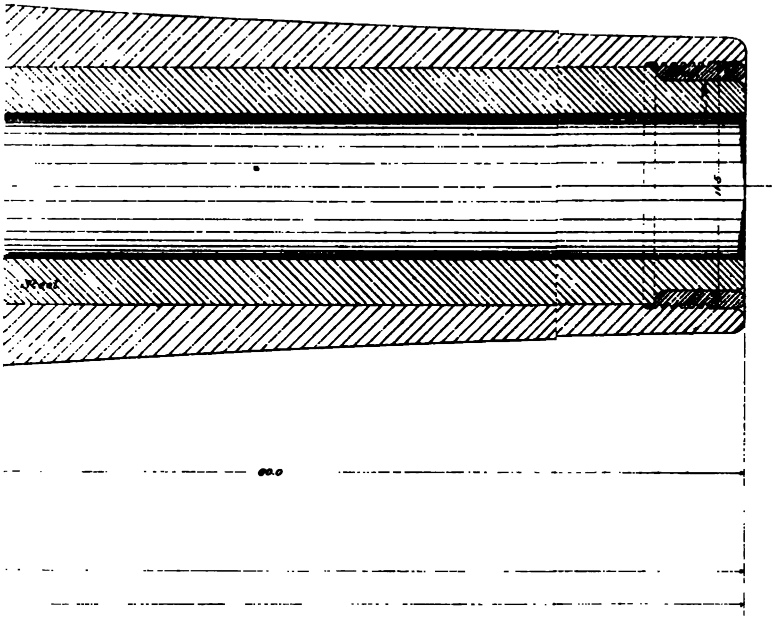
In addition to the 16 breech cups assembled, 6 others are rough threaded preparatory to fitting and insertion in a designated tube.

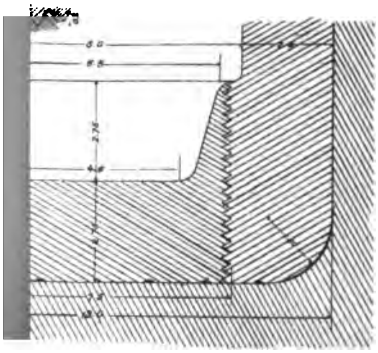
Of the muzzle-collars 14 have been fitted to casings and 13 others are prepared for the threading.

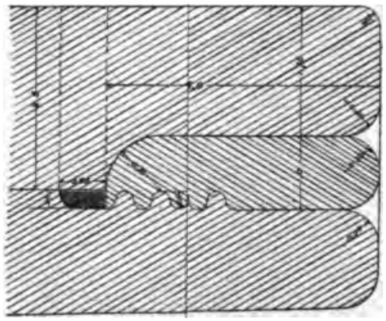
In the inspection of material only one piece has been rejected to date, viz: Breech-cup forging No. 4, for fine seams left exposed in the finished surface of the cup proper. In several of the cast-iron casings small defects have been uncovered in the finished bore near the muzzle, but none which could be considered serious enough to condemn the casing for service.

Very respectfully,

R. BIRNIE, JR.,
Lieutenant of Ordnance.


Steel
11.5
60.0





APPENDIX 46.

REPORT OF THE WORK DONE FOR THE ORDNANCE DEPARTMENT AT THE WORKS OF JONES & LAUGHLINS, PITTSBURGH, PA., DURING THE FISCAL YEAR ENDING JUNE 30, 1885.

BY LIEUT. WILLIAM M. MEDCALFE, ORDNANCE DEPARTMENT.

(2 plates.)

Under contact of June 30, 1884, the firm was called upon to cold roll hirteen steel bars for the 10-inch Woodbridge wire-wound gun.

Twelve of these bars were 24 feet in length, one being a half bar, 12 eet in length, for experimental purposes. They were made of open-earth steel, and were manufactured by the Otis Iron and Steel Comany, of Cleveland, Ohio. Each bar was made from the lower half of 14 inch square ingot, which was rolled and hammered, while hot, down o 4½ inches square.

The bars were now to be reduced by cold rolling to $3\frac{4}{10}$ inches square, n the smallest practicable number of passes.

Before delivery to the contractors the bars were annealed at the Washington navy-yard, under the direction of Dr. W. C. Woodbridge. The following description of the operation is furnished by Dr. Woodbridge:

> The furnace in which the bars were annealed (and subsequently the tube for the 10-inch steel wire-wound gun) was constructed on plans furnished by me for the Ordnance Bureau of the Navy Department, at the Washington navy-yard.
>
> The requirements of the process of annealing are that the article to be annealed hall be heated with uniformity to a temperature which shall reduce the elastic resistance of the material to a very small quantity, and subsequently cooled with such egree of uniformity as not to introduce strains arising from irregular or dissynchronous contraction. Oxidation must also be guarded against.
>
> The furnace, which is represented in the accompanying drawing, was planned with a ew to meeting these requirements. It consists of a long, narrow, and covered rectgular inclosure of brick-work, provided with supports for the tube or bars to be nealed, and with the necessary apertures. The whole is inclosed within end plates d back staves, connected with tie rods. The bricks chosen for its construction re made from the clay commonly employed in the vicinity of Washington for brick king, being selected from a kiln of ordinary building bricks, by attention to the pearances indicating the degree of heat at which they had been burned. It was cessary that they should have sufficient strength to support the weight they were stined to bear, and at the same time that they should be as porous as possible, so at their conductivity for heat might be low. Bricks that had not reached the point incipient vitrification were therefore chosen—such as had attained their full red lor, while they might yet be regarded as "rather soft." The temperature indicated these qualities is above that reached by any part of the walls of the annealing rnace, so that further shrinkage was not to be apprehended.
>
> The cement used in laying the walls was composed of molding-sand, to which out one-fifth part of common clay was added, and enough of a mixture of molasses d water in equal parts to give it the requisite plasticity. This mixture dries without apparent contraction and forms a very firm cement as soon as dried, retaining its rength through all the ascending steps of temperature to the point at which the arbonaceous residue of the sirup is consumed.

To prevent loss of heat through the walls of the furnace by convection, it was painted (or varnished) exteriorly with a solution of silicate of soda, to which Venetian red was added, and with the same mixture, with the further addition of litharge, in the interior. The latter mixture fused at the temperature of annealing.

The covering of the furnace rested on iron plates. It consisted of molding-sand mixed with molasses and water, filled in with light pressure, and covered at the top with closely-fitted slates.

Precautions, too often omitted, were taken to prevent the expansion of the interior iron parts from bringing strains upon the walls, and for keeping the walls dry when not in constant use, by cutting off capillary connection with the ground.

Doors at the ends of the furnace are provided for the insertion of the pieces of steel to be annealed. They are closed when the furnace has received its charge with brick-work laid in such a way as to be easily removed when the annealing is completed.

The doors for the insertion of fuel are wholly below the space occupied by the metal to be annealed, and are at the same time the only outlets for the air admitted for combustion. Draft holes for the admission of air are placed immediately below them. Both doors and draft holes are furnished with stoppers.

The fuel employed is charcoal. No grate bars are needed. Small "peep holes," very much widened vertically, are formed in the walls at a suitable height for viewing the objects to be annealed. Hoods of sheet-iron, connected with draft pipes, are placed above the doors to carry up the escaping gases of combustion, but take no part in promoting the drafts of the furnace.

By the arrangement described, the object to be heated and annealed is placed in what might be called an inverted pool of heated gases, forming a bath from which it appears to take its temperature with great regularity and uniformity. There can be no strong drafts in the furnace, localizing its heat, since the column of heated air to which draft is due does not exceed two feet in height, but this is more than sufficient to procure as rapid combustion as is desirable. The quality of the gases of combustion may be observed as they escape from the partially closed doors, and the supply of fuel (which should be dry charcoal) may be so proportioned to the air admitted as almost entirely to obviate oxidation in heating.

The temperature to which articles of steel are brought for annealing is indicated by a full red color. This heat is maintained for an hour or more, according to the size of the piece, the idea being that more time is probably required for the equalization (or remission) of strains in a large mass than in a small one.

The time devoted to heating the furnace and its contents depends in part upon the necessity of imparting such an amount of heat to the furnace itself that cooling shall be sufficiently gradual.

The bars for the staves of the 10-inch gun before mentioned were all annealed, preparatory to cold rolling, at the same heat. They were piled upon the bearers with small bars of iron between, being spaced about one inch apart, both laterally and vertically.

Heating was continued about thirty-six hours with very gradual progression, the bars attaining a full red heat. The furnace was then closed, and every opening luted. At the expiration of four days the temperature was found to have fallen below the melting point of tin, but apparently not much below. It was not found convenient to remove the bars for more than a week later, the furnace having stood open for some days, and the bars having become quite cold.

The cold rolling of rods for shafting and other purposes has been extensively practiced by the present contractors, and they were probably better equipped for the work than any other firm in the country. The reduction, however, usually made in order to secure a hard and perfectly true surface for shafting, is very slight in comparison to that required by the contract, and grave doubts were entertained by the company as to the possibility of reducing the cross-section one-third without injury to the bars as well as to the rolls. The Department therefore assumed the expense of the rolls, which had to be cast specially for this work.

The first pair of rods was made at Jones & Laughlins. They were of chilled iron, 22 inches outside diameter and 18 inches in length, with a single triangular groove in the center. The angle of the groove was 91° and its depth equal to half the diagonal of the finished bar. Fig. 2 shows the cross section of the groove. The bottom of the groove was formed by a fillet struck with a radius of 0.17 inch.

The rolling was commenced on the 8th of December, 1884. The reduction was made as rapidly as possible, the diagonal of the short bar was compresssed 0.41 inch in 10 breakdowns or 24 passes. Three couplings having broken, the rate of reduction was reduced to 60 breakdowns or 120 passes to the inch, as all the machinery could stand. Six more passes were made when the lower roll broke, the line of fracture coinciding with the bottom of the groove.

On examining the unbroken roll, it was found that the sharp feather edge formed on the corners of the bar, during the reduction, had cut deeply into the bottom of the groove, and the roll showing further considerable wear, it was deemed necessary for the continuance of the work to make two new rolls. The failure of the lower roll was attributed mainly to the formation of a sharp edge on the corners of the bar, which cut into the groove at the bottom line and acted as a wedge to split the roll open. The formation of this cutting edge was favored by the depth of the groove which increased the drag of the bar on the bottom of the groove unnecessarily; by the comparatively small angle of the groove; and by the smallness of the fillet forming the bottom.

To remedy these defects drawings for new rolls were prepared by Dr. Woodbridge, with two grooves having an angle of 93 degrees and a depth considerably less than that of the grooves in the first rolls. The fillet at the bottom of the grooves was made as large as possible, being struck with a radius of 0.3 inch.

Fig. No. 1 shows the form of cross-section of these grooves. The decrease in the depth of the grooves, and the change in their position made by the substitution of double grooves for the single groove added materially to the strength of the roll, besides increasing the lip of the roll by enabling the workmen to roll alternately in each groove. The increased angle and the large fillet at the bottom of the groove tended to prevent the formation of a cutting edge on the bar.

The new rolls were also made by Jones & Laughlins, and the work of cold rolling was resumed February 12, 1885.

It was decided to reduce the bars to the required size, 3.43 inches square, in 118 reducing passes, but this number was subsequently reduced to 109.

Five bars were successfully reduced, the two grooves being used alternately, when the upper roll cracked in two along the bottom of the left-hand groove. Up to within one or two passes before the roll gave way there were no indications of its failure, and it was supposed to be fully able to stand the work required of it. On examining the fracture the chill was found to extend in five or six inches from the circumference all around, and in streaks nearly to the center.

In the opinion of Dr. Woodbridge and the inspector, the roll had received too great a chill and its strength had been thereby impaired. The contractors, however, thought the fracture showed the roll to be a fair one, and further stated that it was impossible to regulate with accuracy the depth of chill.

After visiting, in company with Dr. Woodbridge, a number of works in Pittsburgh, the inspector came to the conclusion that Garrison & Co., had probably the most experience in casting chilled rolls, and as they agreed to guarantee the depth of chill, which was placed at 2 inches, the depth of the grooves being 1½ inch, a new roll was ordered from them, after having received the necessary authority from the Chief of Ordnance.

The new roll was ready and the rolling recommenced on April 22, 1885.

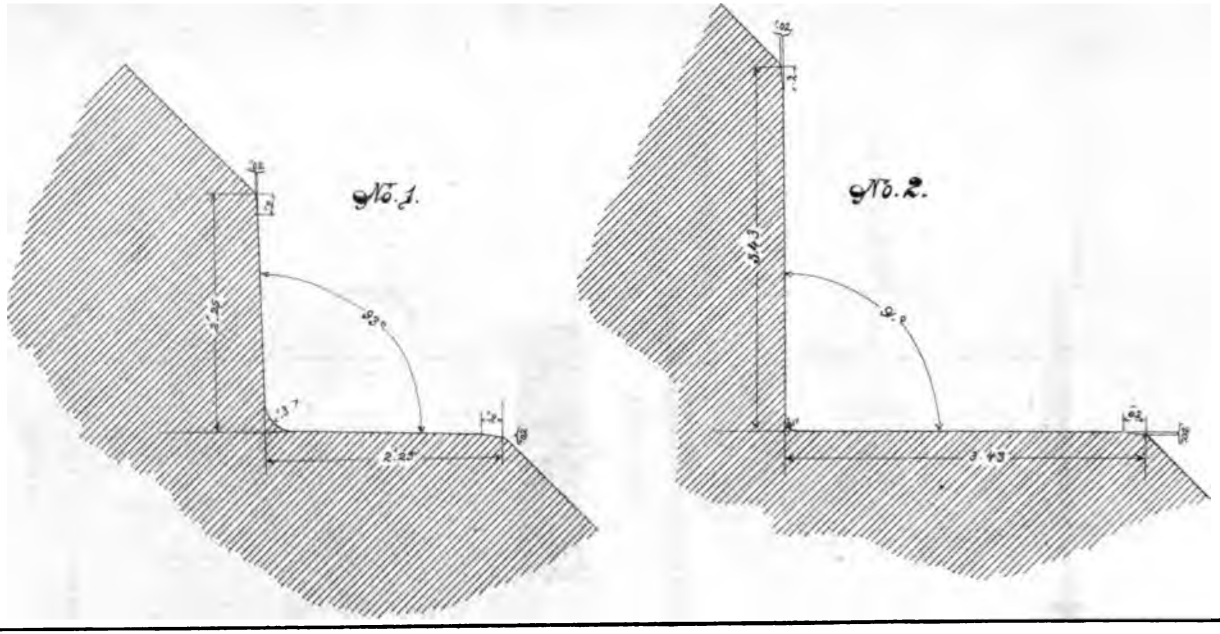
The bars were rolled at the rate of two a day and the operation completed without any accident.

The rolls stood the work well and did not require redressing. They appeared to be perfectly sound and capable of doing considerable further work after the rolling was finished.

The rapidity of reduction was reduced somewhat so as to be on the safe side, from 132 to 140 breakdowns being used to reduce each bar instead of 109 as previously adopted.

The bars were afterwards straightened and shipped to the commanding officer of Watertown Arsenal.

Form of Roll.



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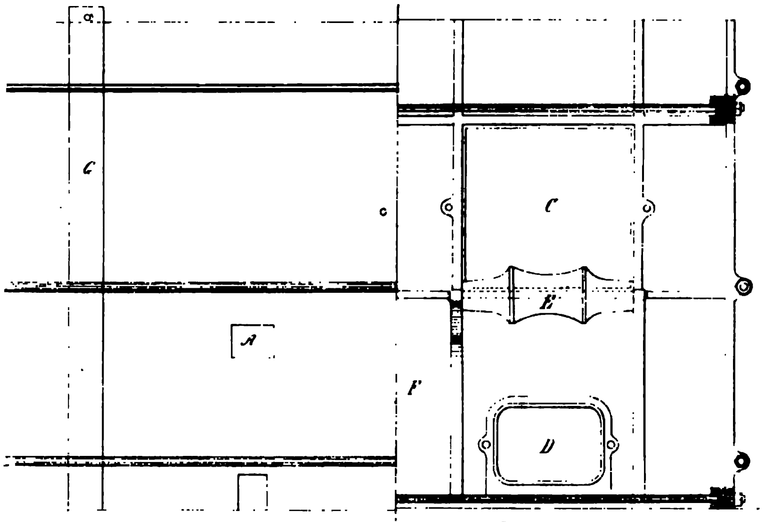
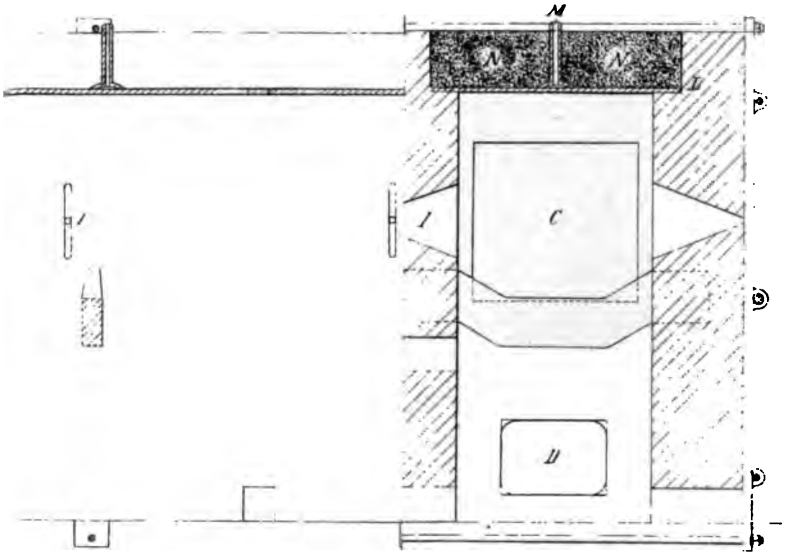
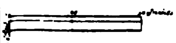


End-View.



Section.



APPENDIX 47.

REPORT OF THE MANUFACTURE OF STEEL GUN-WIRE AT THE TRENTON IRON WORKS DURING THE FISCAL YEAR ENDING JUNE 30, 1885.

BY LIEUT. WILLIAM M. MEDCALFE, ORDNANCE DEPARTMENT.

Under contract of June 30, 1884, the Trenton Iron Company was required to convert 75,000 pounds of steel into wire for gun-construction. The steel was furnished by the Ordnance Department in the form of billets, 2 inches square, and weighing about 80 pounds each.

These billets were manufactured by the Otis Iron and Steel Company. They were of open-hearth steel, and had been required to show the following properties: Tenacity per square inch, not less than 70,000 pounds; ultimate elongation, not less than 30 per cent.; reduction in area of cross-section, 50 per cent. (See tests, Appendix 30, Report of Chief of Ordnance, 1884.)

In the form of wire it was expected that the tenacity would be increased to 160,000 pounds per square inch, and the elastic limit raised from about 40,000 pounds to 110,000 pounds per square inch, sufficient ductility being retained to permit the wire being wrapped around itself without fracture.

Ten specimens taken from the same coil and tested at Watertown Arsenal gave the following results, the distance between measuring-points being 10 inches:

Number.	Tenacity per square inch of original section.	Ultimate elongation.	Reduction in area after rupture.
	Pounds.	*Per cent.*	*Per cent.*
1	178, 150	2. 1	15. 7
2	178, 330	2. 6	15. 7
3	178, 060	2. 0	15. 7
4	177, 960	2. 0	18. 1
5	178, 240	2. 2	15. 7
6	177, 780	1. 4	21. 8
7	176, 850	1. 6	9. 2
8	176, 940	2. 4	19. 9
9	173, 100	2. 3	18. 1
10	171, 760	2. 0	18. 1

The elastic limit in these specimens was not well defined, but was probably in the neighborhood of 100,000 pounds. (See report of test hereto appended.)

To obtain these qualities it was considered necessary to limit the manufacturers to a single annealing, applied after the billets had been rolled into rods, the rods being then drawn without further annealing from 0''.5 to 0''.15 square wire.

This required ten draughts, and as four or five is the largest number usually made before returning the metal to the annealer, the operation was at first necessarily somewhat of an experiment.

The extreme hardness acquired by the wire after several draughts and the square form of cross-section combined to make the action on the draw-plate very severe, and for some time it was doubtful if the ordinary style of draw-plate could be used.

The delivery of the billets was not completed until September 15, 1884. The contract required the completion of the wire six months after the receipt of the steel. The many difficulties experienced, combined with the inherent slowness of the operation, prevented the completion of the work in the time specified. The time allowed was, at the request of the company, extended by the Chief of Ordnance to September 20, 1885.

On June 30, 1885, all the wire was under way in the various stages of manufacture, though but a small amount had been finished—a fact partly due to the uncertainty which had existed as to the best method to be adopted in tinning.

The state of progress at that time was as follows: 10,700 pounds finished wire tinned, 25,600 pounds wire complete as to drawing, 9,325 pounds wire partly drawn, 18,700 pounds ½-inch rods.

The operations through which the billet passes in its transformation into wire are: heating, rolling, pointing, annealing, pickling, lime-coating, baking, lubricating, drawing, and tinning.

HEATING.

The furnaces used for heating the billets are low reverberatory coal-furnaces, and the loss of weight due to oxidation is considerable.

The average loss for cast-steel is about 4.5 per cent. The billets remain in the furnace about an hour, the blast being kept up until they have acquired a full heat. In the case of twenty billets which were rolled separately for experimental purposes, the furnace, which had previously been used for heating iron, was quite hot when the steel was put in; the blast was only required for a short time; and the number of billets being small they were promptly removed from the furnace after reaching a full heat. The loss in weight was only one-half that usually met with.

Each billet was carefully weighed before being placed in the furnace, and again after rolling. The average loss of weight for the twenty billets was 2.47 per cent. A full yellow heat was acquired in 26 minutes, the longest period that any billet remained in the furnace being [illegible] minutes.

While the additional loss of weight usually experienced in heating and rolling large numbers of billets may not be of great importance, the length of time that the billets are exposed to a full heat and the total time they remain in the furnace must largely determine the qualities which the metal will show when drawn into wire.

As will hereafter be noted, a large number of the coils have failed to stand the successive draughts, and have broken in the draw-plate. This is probably due to a variety of causes, but overheating, either in the ingot or billet, more probably in the latter, has been responsible for some of the loss.

Occasional pieces pass successfully through all the ten draughts, but are really worthless for gun-wire on account of brittleness. Such a piece can be taken in the hands and easily snapped in two, while a perfect piece of wire will wind around itself without showing any tendency to fracture.

It is to be regretted that the experiments on the twenty billets mentioned above was unavoidably delayed until all the others had been rolled, as the experience gained would have been valuable in regulating the operations in the heating-furnace. In future I think the billets should be heated in small lots, so that they may be removed promptly after acquiring a full heat, and to enable them to be more closely watched during the operation, thus diminishing the danger of individual billets being burnt or unevenly heated. The furnace should be quite hot when charged, so as not to require the blast to be left on for more than fifteen minutes, thus diminishing the loss, and also the liability of overheating.

ROLLING.

When the billets have acquired a full yellow to near white heat, they are transferred one by one to the rolls, which stand in the immediate vicinity of the heating-furnaces.

The 2-inch square billet is reduced to a ½-inch square rod in nine passes, the total time of passing through the train of nine rolls being only 1¼ minutes. In this time the metal has cooled from a bright yellow to a bright red. On issuing from the rolls the rods are at once coiled on reels, weighed, and then thrown on the floor to cool.

POINTING.

The rods are next pointed to facilitate their entrance into the holes of the draw-plate. This is done by hand. The ends are heated in a blacksmith's fire to a cherry red, and hammered out into long tapering points. five or six inches in length, defective ends being cut off. The pointing is done before annealing, to avoid destroying the softness and ductility of the ends, which would cause them to break off near the holder.

ANNEALING.

As the coils receive but one annealing the manufacturers have endeavored to make it as thorough as possible, the operation lasting nearly twice as long as for ordinary commercial wire.

The annealing pots and furnaces are sunk below the level of the floor of the annealing room. The pots are three feet in diameter and six feet in depth, and are made air-tight. Soft coal is the fuel used. The rods and wire are charged cold, and the pots closed with covers which are luted with clay, to prevent the entrance of air. The oxidation is, however, considerable, and when removed they are covered with a thick scale which has to be removed by the subsequent operation of pickling.

From seven to eight hours is required to heat the rods slowly up to a cherry heat, the progress of the operation being watched by the workmen through peep holes near the base of the annealer. After a proper heat has been acquired the fires are raked out and the rods left to cool in the annealers.

The annealing was generally done on Saturday, and the coils were not removed until Monday morning, the whole operation thus taking forty-eight hours.

The twenty selected billets, which were annealed separately, required seven hours to get a full heat, and were left to cool in the pots twenty-two hours. On being taken out they were still hot enough to blaze a piece of pine wood, or at a temperature estimated to be about 650° F.

The important points to be observed in annealing are: that the rods be heated up to the proper temperature gradually, so that all parts may acquire a uniform heat; the temperature throughout the annealer should be the same; air should be excluded as far as possible to prevent oxidation; the cooling should be conducted very slowly to insure softness and ductility.

The temperature of the annealer was determined at one time by means of heat-tests, cylinders of an alloy of copper and tin in different proportions, prepared by Dr. Woodbridge. These tests were examined after the annealer was opened, and showed that the upper portion of the pot was considerably hotter than the lower, the maximum temperature being in the neighborhood of 1,800° F.

PICKLING.

The rods when cool are cleaned in a pickle of dilute sulphuric acid. Fifteen coils are strung on a wooden reel and lowered into the pickling tub at a time. The latter is made of wood and holds about 380 gallons of the mixture. The bath varies in strength according to the length of time it has been in use. Fresh acid is added from time to time by the workmen, as their judgment dictates.

A newly-prepared bath contains 1 part by weight of oil of vitriol to 30.69 parts of water. It is heated up to about 110° F. before introducing the coils. The time of immersion of course varies with the thickness of the scale to be removed and the strength of the mixture. In cases observed it varied from 40 to 50 minutes. The reel is lifted out from time to time, the coils played upon by a hose, and the progress of the operation observed. When all the oxide has been removed they are thoroughly washed and left to soak for a short time on the floor, so as to acquire what is called a water-coat, which is supposed to increase the adherence of the lime-coating next to be applied.

LIME-COATING AND BAKING.

To prevent the rods from rusting during the succeeding operations they are coated with lime. The mixture consists of two parts rye-flour lees and one part milk of lime. The lees is prepared by stirring two or three pounds of rye-flour in a barrel of water. The coils are dipped in the lime-coating mixture and then taken to the baking oven. This is simply a large drying oven which when filled is closed and raised to a temperature of about 650° F. The coils generally remain in over night, about fifteen hours.

The loss in weight due to pickling varies from a few tenths of a pound to over a pound, averaging for 80-pound billets a little over ½ a pound. So that, taking the usual loss of 4.68 per cent. in rolling and 0.60 per cent. in pickling, an 80-pound billet when it comes to the drawing-block in the form of a coil weighs but 75.8 pounds. The loss, therefore, on 75,000 pounds, the amount furnished the contractors, would be from these causes alone 3,960 pounds.

The coils are lime-coated after each draught and placed over the annealers to dry. After the second draught a light coating of copper is deposited on the wire, to improve the smoothness of its surface and facilitate drawing. For this purpose the coils are immersed in a solution of sulphate of copper, with a slight excess of acid, and lie therein until sufficient copper has been deposited to give a satisfactory coat. The time required varies with the size of the wire, from about one-half an hour after the second draught to five or six minutes after the ninth draught.

DRAWING.

The ½-inch rods are reduced to square wire, 0.15 inch on the side, in ten draughts, the corners being rounded with a radius of 0.01 inch. The ends of the wire are reversed at each successive draught. The bend of the wire in coiling is required, by the terms of the contract, to conform to a cylindrical surface, or the rectangular cross-section of the wire to be either parallel to or at right angles with the axis of the cylinder on which it is wound. This was necessary to prevent the wire receiving a twist as it issued from the draw-plate.

To meet this condition the drum, which was 35⅝ inches in diameter, was placed in front of a stand, upon which the draw-plate traveled, in a direction parallel to the axis of the drum. The plate was held and wedged between the upright arms of a carrier, which was given the required motion by an endless screw, situated in the stand beneath, and driven at such a rate that the successive turns of wire lay close together on the drum. A small engine near the block moved both the drum and carrier. The speed of revolution of the drum was regulated by the throttle-valve of the engine.

The speed of draught varies with the size of the wire, the surface of the drum traveling about 0.250 of a foot per second during the first draught and 0.450 of a foot per second during the tenth. The speed, however, is liable to vary considerably in any one draught, owing to the manner in which it is regulated.

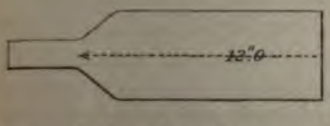
The approximate time required to draw an 80-pound coil through the different holes is as follows:

	Minutes.
First hole	8
Second hole	11
Third hole	13
Fourth hole	15
Fifth hole	19
Sixth hole	25
Seventh hole	29
Eighth hole	30
Ninth hole	36
Tenth hole	45

The speed of draught cannot be increased beyond a certain point for each hole without endangering the success of the operation.

The draw-plates used for the present work are of the so-called *meteor steel*, and have all been obtained from England. The secret of their manufacture is jealously guarded, and so far they have not been successfully duplicated in this country. The work that a plate is called upon to perform, where the wire is to be drawn without annealing as many times as required under the present contract, is very great, and the tendency of the hole to open is only counteracted by using the hardest and most unyielding plates. They are made of crucible steel. Norway iron scrap is used, this being melted with coke.

The plates are of the shape shown in the figure. They are 12 inches long by 5 broad, and are 1¾ inches thick. A separate plate is used for each size or draught. The draw-holes are pricked with a punch and hammer by the workman drawing the wire. They open with a bell-mouth at the outside face of the plate, but are straight and square through the inner half of



the plate's thickness. The operation of pricking is a delicate one and requires considerable skill. The hole must be kept to the exact size and its walls firm. The slightest inaccuracy in striking the punch causes it to break off in the hole. To make the metal about the hole unyielding, the plate is hammered up with a sharp-faced hammer during the operation of pricking. It is laid flat, with its inner face (where the wire emerges) uppermost, and hammered smartly all around the holes. This compresses and spreads the surrounding metal. By alternately hammering and pricking, the hole is brought to the required size.

The punches used are the private property of the workmen and are not ground to any standard, though a taper of one in five is aimed at.

The size of the holes for the different draughts, as laid down by Dr. Woodbridge, are as follows:

Number of draught.	Length of side of square.	Reduction of size.
	Inches.	*Inches.*
1.........	0.4500	0.0500
2.........	0.3963	0.0547
3.........	0.3491	0.0472
4.........	0.3074	0.0417
5.........	0.2708	0.0366
6.........	0.2385	0.0323
7.........	0.2101	0.0284
8.........	0.1850	0.0251
9.........	0.1630	0.0220
10.........	0.1500	0.0130

The sixth and seventh draughts are considered by the workmen to be the most severe, and the ones during which the wire is most likely to break.

At this stage the wire has become very hard and unyielding, the metal has been considerably fatigued, and its ductility impaired. The loss due to breaks would in all probability be diminished by giving the wire a light annealing after the fifth hole, which would restore the metal. To ascertain the change in physical properties which this additional annealing would occasion, one coil was lightly annealed between the fifth and sixth draughts, and a specimen taken from the finished wire was sent to Watertown Arsenal for test. Five specimens, 10 inches in length between shoulders, gave the following results:

	Tenacity per square inch of original section.	Ultimate elongation.	Reduction of area at rupture.
	Pounds.	*Per cent.*	*Per cent.*
1......	130,790	2.3	35.1
2......	130,840	0.35	40.4
3......	131,510	1.2	30.7
4......	128,050	2.3	30.7
5......	130,930	0.8	38.3

The tenacity, though still high, has fallen off about 45,000 pounds per square inch as compared with that obtained from a piece drawn without the additional annealing, while the reduction of area is about doubled.

The ultimate elongation appears to have been but little affected.

After receiving ten holes, the length of a full coil weighing 76 pounds s 1,000 feet.

The wire-drawers, in adjusting the plate, give it a slight cant to the rear, for the purpose, as they express it, of killing the wire, that is, taking from it the tendency to spring out into a large coil, which would become unmanageable when removed from the drum.

The angle made by the plate with a vertical plane was measured during the drawing of some selected billets, and was found to vary from 2° to 8°. Dr. Woodbridge objected to the bend which this method put in the wire while it was passing through the draw-plate, because it tended to extend the metal unequally on the upper and lower faces of the wire. To test the necessity of introducing this bend, two coils were, at his suggestion, drawn without any cant being given the plate. These coils, when removed from the drum and allowed to freely expand, showed a diameter only slightly greater than that of coils which had been drawn with the plate inclined.

LUBRICATING.

The lubricant used is a matter of great importance, and materially affects the success of the operation. Two methods have been employed in the present work. The wet process: In this the coils, just before passing to the drawing-block, are immersed in the copper-coating mixture, consisting of sulphate of copper in solution, with a certain proportion of rye-flour lees. As the coil hangs on the reel from which it is fed to the block, it turns in a trough containing the same mixture and passes to the plate in a wet condition. The copper coating here acts as lubricant, and prevents "cold welding," or adherence of the wire to the walls of the hole.

As this method was found not to give entire satisfaction, a modification was proposed by Dr. Woodbridge, and given a trial. The trough into which the coil dipped when placed on the reel was filled with a compound of glucose and lime-water. The results were not encouraging, and the wet process was finally abandoned in favor of the dry.

In this process the coils, having first received a light coating of copper by being immersed in the coppering solution, are placed on the reel dry. Mutton tallow is used to lubricate the wire as it passes into the hole. The workman stands, knife in hand, and keeps the wire well surrounded with the lubricant. This method has worked well.

According to the terms of the contract the allowed variation in dimensions of the finished wire before tinning was ±0.″001. In the first lot gauged 19 pieces, weighing about 800 pounds, were found in which the variations exceeded that allowed. This generally occurred at but one end of the piece, and as a rule did not exceed ±0.″0015, but in some instances approached 0.″002. As it appeared that the wire-drawers were unable to improve on this degree of accuracy, and as a rigid adherence to the contract in this matter would require the rejection of a large quantity of good wire, the allowed variation was, on the recommendation of the inspector, increased to ±0.″002. Up to the present time only two pieces have been found in which the variation exceeded the latter limit.

BREAKS.

The loss due to failure of the wire to pass successfully through the ten draughts has been large. The scrap and defective wire will make up fully 10 per cent. of the total weight of the coils after rolling.

When it is considered that the steel furnished the contractors was very carefully selected, and that it is pronounced by them to be as good stock as they have ever worked, this high percentage of waste is remarkable.

A variety of causes, which will be noted below, have probably contributed to produce this result, but I think it may be ascribed primarily to the nature of the operations through which the metal is required to pass during its transformation into wire. Ten draughts without annealing is a great deal for the best of metal to be called upon to stand, and although many pieces even after this show sufficient extensibility to be coiled about themselves without breaking, many others will not bear anything like this amount of extension. Now, though overheating the billet would produce brittleness, it cannot, I think, be charged with occasioning all the trouble. The fact seems to be that we are working the metal right up to the limit that it will stand, and any little irregularity in the operation, which in ordinary drawings would be of small consequence, occasions disastrous results.

The scrap consists of short pieces which have broken off in drawing, and which weigh less than twenty pounds, and certain long pieces which have either broken repeatedly or shown other defects, such as notching on the corners, which render further drawing unadvisable.

The defective pieces of wire may be classed under four heads:

1. Those which pull down in the draw-plate without breaking, but afterwards show an almost total lack of flexibility. Such a piece can be easily broken in the hands. Here the metal has probably been overheated or burnt while still in the billet.

2. Pieces which are jointy or notched along the corners. This may be occasioned either by overheating or a defect in the walls of the hole.

3. Pieces which have parted in drawing, giving an irregular fracture; and

4. Those which on breaking show a "pipey" structure. The causes of the last two classes of fracture have not been satisfactorily determined. The pipey structure shown in many cases would seem to indicate that something in the nature of the metal itself determined the break. Indeed, the wire-drawers claimed to be perfectly familiar with the origin of the trouble, assigning it to an excess of silicon in the steel. To settle this, specimens illustrating the different kinds of breaks, as well as a piece of good wire, were sent on to Watertown Arsenal, and analyzed by Captain Pitman, Ordnance Department. The results of the analysis were puzzling, and hardly led to any conclusion as to the cause, though they appeared to dispose of the theory that excess of silicon was the trouble, since the piece which was piped contained the least percentage of silicon of any examined.

In these analyses pieces of five or six inches in length were used, and it is possible that differences in the composition of the steel, existing at the immediate point of fracture, might have been lost sight of in the general result obtained from the whole piece. If minute quantities of filings, taken from the fractured surfaces both at the center and outside of the wire, could be examined, the variations in composition might become apparent.

At the present time the origin of the breaks can in many cases only be conjectured. The following causes may be mentioned as materially influencing the amount of loss:

(1) Character of the metal. Experience so far gained goes to show that the softer billets stand the operation better than the relatively harder ones. Probably in future lots of steel furnished for wire-draw-

ing, 60 per cent. contraction of area had better be required instead of 50 per cent., as in the present case, even at the expense of a sacrifice in the tenacity of the steel in the billet form.

(2) Degree, length, and uniformity of heating secured by the billets.

(3) Nature of the draw-plates used; accuracy and smoothness of the hole. Undoubtedly a number of breaks may be directly charged to some defect in the plate.

(4) Kind of lubricant used. According to the statement of the workmen the loss was greater during the continuance of the wet process than it has been since tallow has been the lubricant employed.

TINNING.

The wire is required to be tinned and wiped in the most perfect manner; and to prevent any alteration in the properties of the metal during the operation, the temperature of the tinning-bath is kept down to 500° F.

Experiments were undertaken to determine the best method of tinning. Three plans were tried.

(1) Tinning as a final operation, after the drawing had been completed; (2) tinning after the ninth hole was passed, the wire receiving the tenth and last hole after the coating of tin was applied; (3) tinning after the eighth hole.

A good coating was obtained by each of these methods, that in which the coat was given after the ninth hole appearing the best. The objection to tinning as a final operation was mainly the difficulty experienced in perfectly wiping the wire. The asbestus cloth used for this purpose was apt to be worn away by the sharp corners of the wire, and on the last portions of a long coil the tin was sometimes found clotted in spots on the sides and edges. It was thought that when the wire received a hole after tinning, the coat was not only more evenly distributed, but also more firmly united to the steel beneath. To settle the question specimens were prepared illustrating the three methods, and sent by direction of the Chief of Ordnance to Watertown Arsenal for examination.

The tests were made by Captain Pitman, Ordnance Department, and had for their object the determination of the relative thickness and evenness of distribution of the coating in the three cases. The results showed a slight advantage in favor of the coating applied after the ninth hole. Subsequent experiments conducted by Dr. Woodbridge to determine the comparative weldability of the tinned wire led to the adoption, however, of the method in which the tin was applied after the completion of the drawing.

A special plant was put up for tinning this wire, but afterwards abandoned for the regular plant used for ordinary commercial wire. In the plant first used the wire, on emerging from the tinning-bath, passed through the wiper and into a metal pipe through which a blast of cold air was forced to cool the coating. The drum on which the wire was coiled was given a motion perpendicular to the wire, or parallel to its axis, the wire passing through two horizontally placed grooved rollers, just before reaching the drum, to keep it from twisting; the object of using the air blast instead of a water bath for cooling being to obviate the necessity of bending the wire during the operation.

One objection to this arrangement was, that owing to the considerable distance between the wiper and drum, necessitated by the cold-air pipe, a large piece at the end of each coil was not tinned. One end had to be attached firmly to the drum and passed through the rollers before the tinning commenced. A leader could not be used, as the joint made by fastening it to the wire would be caught as it passed the guide-rollers. To open the rollers momentarily as the joint approached them would render the wire liable to be caught cornerwise and twisted as it passed to the drum, and when once started on its way through the tinning-bath a coil cannot be stopped, even for a moment, without causing the tin to chill at the wiper and form a lump on the wire.

Another and still more serious objection was the inefficiency of the air blast in cooling and hardening the coating. When the wire reached the drum the tin was still soft, and was found to have rubbed off in spots.

The cold-air method of cooling was therefore abandoned in favor of the ordinary method, in which the wire runs through a water trough.

The plant was that ordinarily used, except that a large drum, 30 inches in diameter, was made for cooling the wire.

The only objection to this change of plant was the possible one of the wire receiving a cant or twist during the operation. This was found, however, not to be the case, the tension being too light to have any permanent effect. Some of the coils have a slight cant, but this has been caused by operations undergone before tinning, probably most often to want of perfect parallelism of the walls of the hole in the draw-plate.

The operation as now performed is as follows: The coil, first soaked in a dilute solution of hydrochloric acid, which has been killed or partially neutralized by lead, is placed on a wooden reel, from which it is fed. After going through a wiping cloth, kept saturated with the acid mixture, it bends down and passes through the bath of molten tin. The tub is built of brick, with the furnace beneath the bath. The temperature of the melted metal is regulated so that a soft pine stick will just smolder in it, or at about 500° F. On emerging from the bath it goes through a guide-plate, where it is wiped by a rope of asbestus fiber wound tightly around it. It next enters the cooling-trough, which is filled with castile soap and water; it is wiped with cotton waste on coming out, and wound on the drum.

The coils always receive two coats, sometimes three, and more rarely four coats are required to give a perfect coating. Any spots of rust on the wire before tinning greatly increase the difficulty of the operation.

APPENDIX 48.

PROGRESS REPORT ON THE 8-INCH YATES BREECH-LOADING RIFLE. BY THE BOARD FOR TESTING RIFLED CANNON, APPOINTED UNDER ACT OF JULY 5, 1884.

This gun was transferred to the "Board for Testing Rifled Cannon, &c.," for test, by instructions from the Chief of Ordnance, U. S. A., dated February 3, 1885.

The gun is converted from a 10-inch Rodman smooth-bore gun, lengthened 2 feet by means of a cast iron extension-piece, and lined with a Nashua steel tube. The Board is not in possession of any data relating to the physical properties of the tube or breech clamps. For detailed description of gun, dimensions, &c., the Board would respectfully refer to the construction report of the 8-inch Yates rifle, made by the Inspector of Ordnance at Boston, Mass.

PRESENCE OF INVENTOR.

The inventor, Colonel Yates, was allowed to be present during the trials, and to make whatever changes he desired in the gas-check or breech mechanism upon the approval of the Chief of Ordnance, U. S. A.

EXPERIMENTS.

These were conducted at the Ordnance Proving Grounds at Sandy Hook, N. J.

PROJECTILES.

The 8-inch Hotchkiss projectiles were used for all the firings.

POWDERS.

Du Pont's hexagonal powders E. V. L. and E. V. F., density 1.750 and granulation 72, were used, as these were the grades of powder used heretofore in trials of 8-inch guns.

RESULTS OF FIRING.

The total number of rounds fired up to the present time is 16. The details of the firing will be found in the firing record and table of enlargements appended to this report. The following table shows the pressures and velocities, with the different charges of powder used.

TABLE I.—*Velocities and pressures.*

[*Gun:* 8-inch Yates breech-loading rifle, lined with a Nashua (N. H.) steel tube. *Projectile:* 8-inch Hotchkiss; weight, 181 pounds *Powder:* Du Pont's hexagonal E V. L.; density, 1.750; granulation, 72. *Instruments:* For velocity, 2 Le Boulengé chronographs (mean taken); for pressure, Crusher gauge. Number of rounds fired with each powder charge, two (and mean taken). Instrumental velocity taken at 109 feet from muzzle.]

Date.	Powder charge.	Instrumental velocity (mean).	Pressure (mean).	Recoil.
1885.	*Pounds.*	*Feet.*	*Pounds sq. inch.*	*Feet.*
March 11	20	1,080.5	*18,000	3.33
March 11	25	1,235	18,725	3.61
March 11 and 12 ..	30	1,384	25,650	4.83
March 12	35	1,493.5	30,175	4.73
Maximum ..	....	1,505	30,800	4.77

* Less than.

The following table gives the additional pressures obtained with powder charges of 35 pounds; velocities not taken.

TABLE II.—*Pressures.*

Number of rounds.	Powde	Weight of projectile.	Pressure (mean).	Remarks.
		Pounds.	*Pounds sq. inch.*	
1	E. V. L.	177	32,825	
4	E. V. L.	181	34,700	Maximum pressure equals 34,825 pounds.
1	E. V. L.	182	34,200	
1	E. V. F.	180	34,175	
1	E. V. F.	181	39,775	The E. V. F. powder gave in this last round a higher pressure than was desired; 35,000 pounds being about the maximum limit fixed.

ENLARGEMENT OF BORE.

The gun was star-gauged before the 1st and after the 5th, 8th, and 16th rounds. The record shows that from the muzzle to 122 inches from the muzzle there was practically no enlargement. After the 5th round the enlargement was perceptible from 122 inches to 136 inches (bottom of rifling) from the muzzle. The enlargement varied from 0.001 inch at 122 inches to 0.006 inch at 136 inches, though the highest pressure was only 26,200 pounds, and that only in the last round.

After the 8th round this enlargement had increased to 0.002 inch at 122 inches, and to 0.015 inch at 136 inches, with the highest pressure equal to 30,800 pounds, which indicates a very soft steel in the tube.

After the 16th round the enlargement of the bore was found to be 0.004 inch at 122 inches and 0.020 inch at 136 inches from the muzzle. The increase in diameter was uniform between these points.

REMARKS.

The tin powder-case was intended to be expanded into the annular grooves cut on the interior of the brass gas-check, and to be withdrawn with the "cartridge-head" or gas-check. In no case did it act as intended. The pewter bottom of the can became detached each time it was used, and the case remained in the bore and was removed with a rammer. This tin case is useless and dangerous in that if, by accident, it should be left in the bore, it might cause wedging of the shot and endanger the gun. The long brass gas-check did not act satisfactorily, as in firing it was swaged out, becoming firmly sealed in the bore, and rendered the opening of the breech-clamps difficult; in fact, practically converting the gun into a muzzle-loader. This gas-check, even after the reduction to 6 inches in length and turning the interior to cup-shape, had to be removed by ramming from the muzzle. At the 9th round a steel gas-check 9 inches long was substituted for the brass one, but still a resort to ramming from the muzzle was necessary for removal.

At the 14th round a compound gas-check, consisting of copper and steel, was substituted, which was removable by the extractor.

The difficulties encountered in opening the breech mechanism are shown in the firing record. The locking latches and locking-plate not being able to hold the clamps together in firing, the rear end of the clamps has been turned off, leaving a cylindrical projection—one-half on each clamp—over which is fitted a circular retaining-cap of steel to prevent the clamps flying open and striking the cheeks of the gun-carriage at each fire, as has been found to occur. (See firing record.)

In order to reduce the pressure in the bore, at Colonel Yates's request (see his letter of May 8, 1885, Ordnance Office file 104 I of 1885) and with the approval of the Chief of Ordnance, the Board is having the chamber lengthened 2 inches, giving more air space and diminishing the density of loading. Colonel Yates has also requested that a radial vent be provided instead of the axial one first used.

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F. H. PARKER,
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GEO. W. McKEE,
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D. A. LYLE,
Captain of Ordnance.

Record of firing with 8-inch Yates breech-loading rif

	Number of fire.	Time.	Powder.		Projectile.		Elevation.	Pressure per square inch of bore (new crusher).	Instrumental velocity 100 feet from muzzle.	Recoil.
			Kind.	Weight.	Kind.	Weight.				
		1885.		*Lbs.*		*Lbs.*	′	*Lbs.*	*Feet.*	*Feet.*
A. M.—Barometer, 30.405; thermometer, 21.7; humidity, 58.	1	Mar. 11	Du Pont's Hexagonal E. V. L. Density, 1.750; granulation, 72.	20	Hotchkiss shot (new).	181	—35	18,000	1,086	[illegible]
P. M.—Barometer, 30.311; thermometer, 28.8; humidity, 67.	2	Mar. 11		20		181	—14	18,000	1,075	[illegible]
	3	Mar. 11		25		181	—20	19,000	1,296	[illegible]
	4	Mar. 11		25		181	—20	18,450	1,234	[illegible]
	5	Mar. 11		30		181	—30	26,200	1,381	[illegible]
Barometer, 30.037; thermometer, 34.1; humidity, 69. A. M.	6	Mar. 12		30		181	—25	25,100	1,387	[illegible]
A. M.	7	Mar. 12		35		181	—30	30,800	1,505	4.77
P. M.	8	Mar. 12		35		181	—30	29,550	1,482	[illegible]
A. M.—Barometer, 29.813; thermometer, 49.7; humidity, 88.	9	Apr. 8		35	Hotchkiss.	182	—35	34,200 (Old crusher.)	....	[illegible]
	10	Apr. 8		35		181	—35	34,400	....	[illegible]
P. M.—Barometer, 30.169; thermometer, 76.2; humidity, 36.	11	Apr. 21		35	Hotchkiss new.	181	—35	(Crusher.) 34,925	....	[illegible]
	12	Apr. 21		35		181	—35	34,875	....	[illegible]

at Sandy Hook, N. J., from March 11 *to May* 6, 1885.

Wind, strength, and direction.			Special remarks about each fire, such as effect on piece, sound of projectile in flight, scattering of fragments, &c.
From rear and right 43°; 24 miles an hour.		Fired into sand butt.	The tin powder-case was cut off to a length of 12½ inches to adapt it to the reduced charge. Opened with some difficulty after firing by hammering the lever. The gas-check could not be removed by extractor, but was driven out from muzzle with a rammer. There were traces of gas on outer surface of gas check, near the front part, but no escape in this or subsequent rounds.
			The tin powder-case was cut off to a length of 12½ inches to adapt it to the reduced charge. Opened after firing with slightly less difficulty; gas-check removed as before.
			Tin powder-case cut to length of cartridge. Gas-check had been turned down over lip $\frac{1}{16}$ inch and slightly eased over outer surface, including base. Four men were required, with rope on end of handspike, to open gun after firing, and even more on heavy timber at muzzle to eject gas-check.
			Tin powder-case cut to length of cartridge. Gas-check had been turned down over lip $\frac{1}{16}$ inch and slightly eased over outer surface, including base. Four men were required, with rope on end of handspike, to open gun after firing and even more on heavy timber at muzzle to eject gas-check. The right half of breech closure up to this round was alone bearing properly.
			Before this round the brass gas-check was slightly filed down on the outside so as to fit more easily in chamber, and after each round from 8 to 10 men, working on a heavy timber in the bore, had the greatest difficulty in removing it. Breech driven open by wedges.
From rear and right 43°.	7 miles an hour.		Before this round the brass check was slightly filed down on outside so as to fit it more easily in chamber. The breech closure was found slightly open after each round, but at this one it was open to the extent of 0".175, just above the firing pin. Locking spring broke.
	7		Before this round the brass gas-check was slightly filed down on the outside so as to fit it more easily in chamber. Breech closure opened 0".275. Lock wired down. Breech driven open by wedges. The left side of breech closure found now to be bearing.
	16		Gas-check cut to 6 inches length and hemispherical base reamed out to cup shape and generally eased on outside. Breech closure opened 0".300. Lock wired down. Breech opened with less difficulty with handspike and rope, and gas-check removed with much less difficulty by timber in bore. Gun star-gauged before 1st and after 5th and 8th rounds.
From front and left 43°; 6 miles an hour.			Breech opened 2½ inches. Steel gas-check, 9" long, used. Removed easily by timber in bore of gun.
			Breech opened 3 inches. Cartridge bag and no tin case used. Check removed as above. Left lever pin broken. There were two failures to fire, due to the firing pin striking steel gas-check instead of head of priming cartridge.
From front and left 43°; 16 miles an hour.			Steel gas-check and new lever pins inserted. Before firing this round the old locking catch was replaced by a new and heavier one of steel. Breech closure open 2.8 inches, having first struck cheeks of carriage and rebounded. Catch broken. Gas-check removed by extractor. No escape of gas except through vent.
			Steel gas-check. Locking catch wired down. Breech closure opened 1½ inches, having first struck cheeks of carriage, as before. Gas-check removed by light taps with rammer from muzzle. Escape of gas through vent, as before. All lever pins broken.

Record of firing with 8-inch Yates breech-loading rifle at Sandy

	Number of fire.	Time.	Powder.		Projectile.		Elevation.	Pressure per square inch of bore (crusher).	Instrumental velocity 109 feet from muzzle.	Recoil.
			Kind.	Weight.	Kind.	Weight.				
		1885.		*Lbs.*		*Lbs.*	′	*Lbs.*	*Feet.*	*Feet.*
P. M.—Barometer, 29.736; thermometer, 50.1; humidity, 77.	13	Apr. 28	Du Pont's Hexagonal E. V. L. Density, 1.750; granulation, 72.	35	Hotchkiss, new.	181	—35	34, 600	....	To buffers.
A. M.—Barometer, 29.540; thermometer, 44.1; humidity, 66.	14	Apr. 29		35		177	—35	32, 825	....	To buffers.
P. M.—Barometer, 29.959; thermometer, 53.2; humidity, 66.	15	May 5	Du Pont's Hexagonal E. V. F. Density, 1.750; granulation, 72.	35		180	—35	34, 175	....	To buffers.
A. M.—Barometer, 29.876; thermometer, 48.2; humidity, 90.	16	May 6		35		181	—35	39, 775	....	To buffers.

After the 1054th round the gun was star-gauged while hot, and again after it became cold, to ascertain the amount of the enlargement due to the heat developed in firing. The table given below shows the enlargements with the gun hot and cold, together with the differences due to the heat:

Distance from the muzzle.	Enlargements of the bore after 1054th round with the gun.		
	Hot.	Cold.	Differences.
	Inch.	*Inch.*	*Inch.*
1 inch	0.010	0.005	0.005
10 inches	.013	.006	.007
26 inches	.014	.009	.005
36 inches	.016	.010	.006
46 inches	.018	.010	.008
56 inches	.018	.012	.006
60 inches	.018	.013	.005
65 inches	.021	.015	.006
70 inches	.023	.019	.004

ALTERATION OF MODEL.

The Board decided, on March 12 and April 2, 1885, to recommend certain alterations in the model. Subsequent to this action the details and outlines of the 3.2-inch steel breech-loading rifle were changed and settled by correspondence between the Ordnance Board and the Chief of Ordnance, United States Army; therefore no further action in regard to the subject has been taken or is necessary on the part of this Board.

OPINION.

The 3.2-inch breech-loading steel rifle has been "subjected to the proper test, including such rapid firing as a like gun would be likely to be subjected to in actual battle, for the determination of the endurance of the same," to the satisfaction of the Board.

RECOMMENDATION.

The Board would respectfully recommend that the 3.2-inch breech-loading steel rifle, or its modification, heretofore mentioned, as a suitable gun to "be put to use in the Government service."

T. G. BAYLOR,
Colonel of Ordnance, President of the Board.
F. H. PARKER,
Major of Ordnance.
GEO. W. McKEE,
Major of Ordnance.
CHARLES SHALER,
Captain of Ordnance.
D. A. LYLE,
Captain of Ordnance.

TABLE I.—*Pressures, velocities, and recoils.*

[*Gun:* 3.2-inch breech-loading rifle (steel). *Projectile:* Solid band experimental shell. *Band:* Copper, 3.3 inches diameter; 0.5 inch wide; beveled front and rear. *Weight of projectile:* 13 pounds. *Weight of powder charge:* 3 pounds 8 ounces—3.5 pounds. *Pressure gauge:* Crusher (English). *Velocimeter:* Le Boulengé.]

Number of rounds.	Number of fire.	Date.	Powder.				Projectile.	Elevation.	Pressure per square inch.	Instrumental velocities from muzzle in feet.	Recoil.	Carriage.
			Kind.		Density.	Granulation.						
			Maker.	Marks.								
		1884.						° ′	*Pounds.*	*At* 100 *ft.*	*Feet.*	
1	245	Oct. 15	DuPont	I. K. D	1.725	2,200	New	—30	30,700	1,663	8.83	Iron[1].
2	265	Oct. 22	DuPont	I. K. D	1.725	2,200	Old	+30	31,900	1,661	10	Iron[2].
3	356	Nov. 20	DuPont	I. K. D	1.725	2,200	Old	—30	30,025	1,631	11.67	Iron.
4	406	Nov. 29	DuPont	I. K. D	1.725	2,200	Old	—30	30,725	1,639	9.83	Iron.
Mean									30,837	1,648+	10.08+	
										At 128 *ft.*		
1	461	Dec. 30	DuPont	L. X	1.706	270	Old	0	30,600	1,626	13.5	Siege.
2	464	Dec. 30	DuPont	L. X	1.706	270	Old	0	31,300	1,617	11	Siege.
3	465	Dec. 30	DuPont	L. X	1.706	270	Old	0	29,500	1,616	11.5	Siege.
4	466	Dec. 30	DuPont	L. X	1.706	270	Old	0	32,100	1,627	12	Siege[3].
Mean									30,875	1,621+	12	
1	467	Dec. 31	DuPont	L. X	1.706	270	Old	0	33,100	1,631	8	Iron.
2	468	Dec. 31	DuPont	L. X	1.706	270	Old	0	29,500	1,617	8	Iron.
3	469	Dec. 31	DuPont	L. X	1.706	270	Old	0	31,200	1,621	7.5	Iron.
4	470	Dec. 31	DuPont	L. X	1.706	270	Old	0	31,400	1,634	8	Iron.
5	471	Dec. 31	DuPont	L. X	1.706	270	Old	0	31,450	1,637	8	Iron.
6	472	Dec. 31	DuPont	L. X	1.706	270	Old	0	30,600	1,627	7.5	Iron.
Mean									31,208	1,627	7.83+	
		1885.								*At* 107 *ft.*		
1	501	Mar. 18	DuPont	L. X. A	1.706	270		0	29,300	1,572	10	Steel carriage; previously fired and repaired at Watervliet Arsenal.[4]
2	502	Mar. 18	DuPont	L. X. A	1.706	270		0	30,525	1,592	10	
3	503	Mar. 18	DuPont	L. X. A	1.706	270		0	28,800	1,579	10	
4	504	Mar. 18	DuPont	L. X. A	1.706	270		0	28,450	1,575	10	
5	505	Mar. 18	DuPont	L. X. A	1.706	270		0	28,000	1,565	10	
6	506	Mar. 18	DuPont	L. X. A	1.706	270		0	28,500	1,586	10	
Mean									28,929	1,581+	10	

[1] Iron carriage with stiffened cheeks. (Watervliet Arsenal.)

[2] Gun lashed to stock to prevent springing.

[3] Trail broke.

[4] Fired in sand butt to try powder.

Table of enlargements of 8-inch Yates breech-loading rifle—Continued.

Inches from muzzle.	Original play of tube.	Original diameter of bore.	Enlargements, including "setting up" of tube, after—		
			5 rounds.	8 rounds.	16 rounds.
	Inches.	*Inches.*			
42	.00475	8.001	0.001	0.001	0.000
40	.0045	8.002	.000	.000	—.001
38	.005	8.002	.000	.000	—.001
36	.004	8.002	.000	.000	.000
34	.004	8.002	.001	.001	.000
32	.003	8.003	.001	.001	.000
30	.0025	8.003	.000	.001	—.001
28	.002	8.004	.000	.000	—.001
26	.004	8.004	.000	.000	.000
24	.0025	8.005	—.001	.000	.000
22	.0035	8.005	—.001	.000	.000
20	.0025	8.006	—.001	—.001	—.001
18	.00325	8.006	.000	.000	—.001
16	.0065	8.006	.000	.000	—.001
14	.006	8.006	.000	.000	—.001
12	.0045	8.006	.002	.002	.002
10	.00625	8.007	.001	.000	.002
8	.006	8.006	.000	.000	.000
6	.0045	8.007	.000	.001	.001
4	....	8.014	.000	—.001	—.003
2	....	8.007	.000	.000	.000
1	....	8.007	.000	.000	—.001

APPENDIX 49.

TRIAL OF THE 3.2-INCH BREECH-LOADING STEEL RIFLE, BY THE BOARD FOR TESTING RIFLED CANNON, &c., APPOINTED UNDER THE ACT OF CONGRESS APPROVED JULY 5, 1884.

(3 plates.)

The 3.2-inch breech-loading steel rifle was transferred to this Board by the Ordnance Board on August 1, 1884, pursuant to the letter of the Chief of Ordnance, dated July 24, 1884.

The description of the gun is given in the construction report from Watertown Arsenal, made by Maj. F. H. Parker, Ordnance Department (see Report of Chief of Ordnance, 1884, appendix 33, pages 509, *et seq.*), and in Report No. 25 of the Ordnance Board for 1884.

FIRINGS.

The first 60 rounds were fired by the Ordnance Board before the transfer to this Board. The report of this firing will be found in Appendix 14, pages 141, *et seq.*, Report of Chief of Ordnance for 1884.

The next 184 rounds were fired by this Board, making 244 rounds in all, and the results given in its progress report published as Appendix 22, Report of Chief of Ordnance for 1884, pages 277 *et seq.*

The firings covered by this report extend from the 245th to the 1800th round, both inclusive, or 1,556 rounds.

The firing records appended and forming part of this report contain all the details of the trials. The total number of rounds fired from this gun is 1,800.

CARRIAGES.

These call for no special remark since the gun alone comes within the province of the Board's action. It may be stated, however, that different carriages were used during the trials, viz, the steel carriage made at Watervliet Arsenal, an old iron 12-pounder field-carriage, and the 3[illegible]-pounder Parrott carriage.

PROJECTILES.

The projectiles chiefly used in the trials were the solid-band experimental shell; copper band, 3.3 inches in diameter, 0.5 inches wide—beveled front and rear—weight 13 pounds (See Plate I, Ordnance Board Report; Appendix 15, Report of Chief of Ordnance, 1884, page 155.)

Some experimental shrapnel were also fired. The classification and number of rounds fired with each kind is given below.

TABLE A.—*Projectiles used during the firing.*

[*Classification;* A. Solid-band experimental shell; band, 3.3″ diameter, 0.5″ wide; beveled front and rear; weight, 13 pounds. B. Experimental shrapnel received from Watertown Arsenal April 15, 1885; weight, 13 pounds. C. Shrapnel; brass band; weight, 12.5 pounds. D. Same as A, with head cut off and brass head from shrapnel screwed on; weight, 12 pounds. Metallic time-fuzes set to explode in 5 seconds. In round 1,200 shell burst in or near gun. E. Same as C. Plunger from German fuze with wings off.]

Projectile.	No. of rounds.	No. of fire.	
		From—	To—
Class A ...	757	1	757
Class B	1	....	758
Class C	1	....	759
Class B ...	4	760	763
Class C	3	764	766
Class A	34	767	800
Class E	1	....	801
Class A	366	802	1, 167
Class B	1	....	1, 168
Class C* ...	4	1, 169	1, 172
Class A	23	1, 173	1, 195
Class B	3	1, 196	1, 198
Class D	2	1, 109	1, 200
Class A	600	1, 201	1, 800
	1, 800		

* Weight, 12.75 pounds.

POWDERS.

Du Pont's powders were used throughout the experiments. The following kinds were employed: IKD and IKB, each having a density = 1.725, and granulation of 2,200; LX, LXA, LXB, each with density = 1.706, granulation 270; and LY, with a density = 1.662, and granulation 270.

Only 2 rounds were fired with LY powder, 3 with IKB, 19 with LX, and 142 with LXA.

The principal firing was done with the IKD and LXB powders, the former being used in 790 rounds and the latter in 600 rounds, making 1,556 rounds fired since date of report upon first 244 rounds.

GAS-CHECKS.

Two kinds of gas-checks were used—the Freyre and De Bange. These are described and figured in the report of the Ordnance Board published as Appendix 14 in Report of Chief of Ordnance for 1884, pages 141 *et seq.*

EXPERIMENTS.

These were made at the ordnance proving-grounds at Sandy Hook, New Jersey.

RESULTS OF FIRING.

The details of the firing trials are given in the firing records and table of enlargements of bore and chamber appended and forming part of this report.

PRESSURES AND VELOCITIES.

A summary of the pressures and velocities obtained with the several kinds of powder, using a charge of 3.5 pounds with a 13-pound projectile, is given below in Table B.

The complete tabulation of pressures and velocities for the above charge will be found appended in Table I.

TABLE B.—*Abstract of pressures and velocities.*

[Weight of powder-charge, 3.5 pounds; weight of projectile, 13 pounds.]

Mean of rounds.	Kind.	Instrumental velocity.		Pressure per square inch.
		From muzzle.	Velocity per second.	
		Feet.	*Feet.*	*Pounds.*
4	IKD	100	1,648	30, [illegible] 7
3		100	1,624	....
3		100	1,630	32,000
3	IKB....	100	1,644	30,591
4	LX	128	1,621	30,875
6		128	1,627	31,208
6	LXA	107	1,581	28,929
4		100	1,594	....
1		100	1,583	....
9		100	1,595	....
6	LXB....	106	1,686	35,933

Table II gives all the pressures and velocities taken in which some of the elements, such as weight of powder-charge, &c., differed from the conditions given in Table I.

The LXB powder gives higher pressures and velocities than the IKD powder. With 3.5-pound charges LXB gave a mean velocity of 1,686 feet per second with a pressure of 35,933 pounds per square inch. In using the Freyre gas-check the powder space is greater than with the De Bange, and the charge was increased to 3.75 pounds to give about the same density of loading and maintain the pressures and velocities at about same as those obtained with the 3.5-pound charge and De Bange check.

The following is a summary of the velocities and pressures obtained with 3.75-pound charges of LXB powder:

TABLE C.—*Abstract of pressures and velocities obtained with 3.75 pounds of LXB powder.*

Mean of rounds.	Pressure per square inch.	Velocity per second.	Remarks.
	Pounds.	*Feet.*	
2	36,100	1,715	
3	34,600	1,740*	Gun cold.
3	35,083	1,748.6	Gun hot.

* The mean of the first two rounds in this group is 1,747 feet per second. The third round, for some reason, dropped to 1,728 feet per second, which lowered the mean to 1,740.3 feet per second.

RANGE.

The ranges of this gun, for differences of 2° in elevation, were determined beginning with 2° and ending with 20° elevation, the limit permitted by the carriage. The time of flight and deflection of the projectiles were also observed. Table III shows all the details of the firing for range. A summary of this table is given below in Table D.

TABLE D.—*Time of flight, maximum, minimum, and mean ranges and deflection of projectiles for the 3.2-inch steel field-gun.*

Elevation.	Time of flight.	Range.			Deflection.			Recoil.	Axis of gun above level of sea.	Wind.	
		Max.	Min.	Mean.	Max.	Min.	Mean.			Direction from—	Velocity per hour.
°	"	*Yards.*	*Yards.*	*Yards.*	*Yards.*	*Yards.*	*Yards.*	*Feet.*	*Feet.*		*Miles.*
2	4	1, 608	1, 566	1, 584. 9	*2. 75	†0 75	*0. 3	9. 8	14. 3	Front and left, 32° ..	9
4	6. 6+	2, 376	2, 348	2, 364. 2	†2. 75	*0. 25	†1. 5	9. 6	16. 6	Front, ——	6
6	9	3, 054	3, 022	3, 036. 3	*1. 5	.....	*0. 7	8. 5	12	Front and left, 32° ..	6
8	11. 45	3, 653	3, 621	3, 635. 6	†8	†6	†6. 9	8. 07	12. 9	Front and left, 32° ..	6
10	13. 8	4, 166	4, 128	4, 150. 5	†18	†12	†15	8. 125	12. 7	Front and left, 32° ..	6
12	15. 7	4, 853	4, 789	4, 8[illegible]	*49. 25	*45	*46. 4	8. 07	13. 2	Rear and right, 36° .	20
14	17. 9	5, 314	5, 224	5, 270. 5	*37. 25	*28	*31. 52	8	13. 7	Rear and right, 36° .	20
16	20	5, 716	5, 667	5, 690. 3	*38. 25	*23	*29. 25	8. 16	13. 9	Rear and right, 36° .	20
18	22	6, 155	6, 031	6, 096. 7	†89. 5	*31	†35. 35	7. 825	‡14. 2 §13. 2	Rear and right, 36° Rear	20 11
20	24+	‖6, 564	6, 414	6, 479. 1	†101. 75	†89	†95. 6	7	12. 8	Rear	11

* Left. † Right. ‡ First five rounds. § Second five rounds.
‖ Greatest range attained, 3. 73 miles.

EXTREME RANGE.

Several attempts were made to obtain the extreme range under angles greater than 20°, but without success, due to the impossibility of seeing the small splash made by the projectile when it struck the water at such long distances.

ACCURACY.

1.—*Mean deviation.*

	Distance of target from gun.		
	620 feet.	1 mile.	1 mile.
	Feet.	*Feet.*	*Feet.*
Mean vertical deviation from center of impact .	. 27	1 99	1. 76
Mean horizontal deviation from center of impact.	. 43	3. 20	1. 63
Mean deviation from center of impact.....	. 51	3. 77	2. 40
Kind of carriage used............................	Old iron field.	30-pdr. Parrott.	30-pdr. Parrott.

2.—*Accuracy at 620 feet.*

[*Date:* April 15, 1885. *Gun:* 3".2 breech-loading rifle (steel field-gun). *Carriage:* Old iron field-carriage. *Powder:* Kind, Du Pont's LX; density = 1.706; granulation = 270; weight of charge, 3.5 pounds. *Projectile:* Kind, solid-band experimental shell; band, 3".3 in diameter, 0".5 wide; beveled front and rear weight of = 13 pounds. *Elevation* = 0°. *Recoil* = maximum, 17'.5; minimum, 7'.08; mean, 12'.20. *Number of fire* = 703 to 709. *Number of rounds* = 7. *Target:* Distance = 620 feet from gun; size = 6 by 7 feet. *Wind:* Direction from rear and right, 87°; force, 16 miles per hour.]

Round.	Distance from center of target.				Distance from center of impact.			
	Vertical.		Horizontal.		Vertical.		Horizontal.	
	Above.	Below.	Right.	Left.	Above.	Below.	Right.	Left.
	Feet.	*Feet.*	*Feet.*	*Feet.*	*Feet.*	*Feet.*	*Feet.*	*Feet.*
1	0. 67	....	....	0. 42	0. 22	....	....	0. 06
2	0. 67	....	....	0. 12	0. 22	....	0. 24	....
3	0. 17	....	....	1. 33	....	0. 28	....	0. 97
4	0. 58	....	0. 36	....	0. 13	....	0. 72	....
5	0. 13	....	....	0. 08	....	0. 32	0. 28	....
6	0. 10	....	....	0. 09	....	0. 35	0. 27	....
7	0. 83	....	......	0. 84	0. 38	....	....	0. 48
	3. 15	....	0. 36	2. 88	0. 95	0. 95	1. 51	1. 51
	3. 15 ÷ 7 = 0. 45		2. 52 ÷ 7 = 0. 36		1. 90 ÷ 7 = 0. 27		3. 02 ÷ 7 = 0. 43	

Mean vertical deviation from center of impact, 0.27 feet.
Mean horizontal deviation from center of impact, 0.43 feet.
Mean deviation from center of impact, 0.51 feet.

3.—*Accuracy at 1 mile.*

[*Date:* April 1, 1885. *Gun*: 3".2 breech-loading rifle (steel field-gun.) *Carriage:* 30-pounder Parrott. *Powder:* Kind, Dupont's LXA; density, 1.706; granulation, 270; weight of charge, 3.5 pounds. *Projectile:* Kind, solid-band experimental shell; band, 3".0 diameter, 0".5 wide, beveled front and rear; weight of = 13 pounds; instrumental velocity, at 100 feet from muzzle, 1,595 feet per second. *Elevation:* 2° 35'. *Recoil:* Maximum, 3'.72; minimum, 3'.00; mean, 3'.36. *Number of fire:* [illegible] *Number of rounds:* 9 *Target:* Distance, 1 mile from gun; size, 20' by 40'; axis of gun, 5'.8 above center of bull's eye of target. *Wind:* Direction from rear and right, 87°; force, first four rounds, 12 miles per hour; last five rounds, 14 miles per hour.]

Round.	Distance from center of target.				Distance from center of impact.			
	Vertical.		Horizontal.		Vertical.		Horizontal.	
	Above.	Below.	Right.	Left.	Above.	Below.	Right.	Left.
	Feet.	*Feet.*	*Feet.*	*Feet.*	*Feet.*	*Feet.*	*Feet.*	*Feet.*
1	....	0.50	...	11.00	1.63	....	....	6.47
2	....	5.00	1.68	....	....	2.87	6.21	....
3*	....	....	....	....	....	....	....	....
4	....	4.34	....	5.75	....	2.21	....	1.23
5	....	5.00	....	3.00	....	2.87	1.53	....
6	....	1.34	....	9.00	0.79	....	....	4.47
7	....	0.18	....	1.00	1.95	....	3.53	....
8	0.32	....	....	3.00	2.45	....	1.53	....
9	....	1.00	....	5.17	1.13	....	....	0.64
	0.32	17.36	1.68	37.92	7.95	7.95	12.80	12.80
	17.04+8=2.13		36.24 ÷ 8=4.53		15.90+8=1.99		25.60+8=3.20	

* Under target.

Mean vertical deviation from center of impact, 1.99 feet.
Mean horizontal deviation from center of impact, 3.20 feet.
Mean deviation from center of impact, 3.77 feet.

4.—*Accuracy at 1 mile.*

[*Date:* April 16, 1885. *Gun:* 3".2 breech loading rifle (steel field-gun). *Carriage:* 30-pounder Parrott. *Powder:* Kind. Dupont's LXA; density, 1.706; granulation, 270; weight, 3.5 pounds. *Projectile:* Kind, solid-band experimental shell; band, 3".3 diameter, 0".5 wide, beveled front and rear; weight of 13 pounds. *Elevation:* 2° 35'. *Recoil:* Maximum, 3'.83; minimum, 2'.75; mean, 3'.29. *Number of fire:* 749 to 757. *Number of rounds:* 9. *Target:* Distance, 1 mile from gun; size, 20' by 40'. *Wind:* Direction of first six rounds, from rear and left, 3°; for seventh round, from front and right, 40°; for eight and ninth round, from rear and left, 3°. *Force:* First round, 12 miles; second, 10 miles; third, 12 miles; fourth, fifth, and sixth, 11 miles; seventh, 6 miles; eight and ninth, 4 miles, per hour.]

Round.	Distance from center of target.				Distance from center of impact.			
	Vertical.		Horizontal.		Vertical.		Horizontal.	
	Above.	Below.	Right.	Left.	Above.	Below.	Right.	Left.
	Feet.	*Feet.*	*Feet.*	*Feet.*	*Feet.*	*Feet.*	*Feet.*	*Feet.*
1	....	3.50	2.66	....	....	0.81	2.92	....
2	....	3.50	....	2.50	....	0.81	....	2.24
3	....	2.00	....	0.75	....	2.31	....	0.49
4	....	6.98	0.33	....	2.67	....	0.59	....
5	....	8.00	0.16	....	3.69	....	0.42	....
6	....	2.00	....	3.00	....	2.31	....	2.74
7*	....	....	....	....	....	....	....	....
8	....	3.50	2.34	....	....	0.81	2.60	....
9	....	5.00	....	1.32	0.69	....	....	1.06
	....	34.48	5.49	7.57	7.05	7.05	6.53	6.53
	34.48+8=4.31		2.08+8=0.26		14.10+8=1.76		13.06+8=1.63	

* Under target.

Mean vertical deviation from center of impact, 1.76 feet.
Mean horizontal deviation from center of impact, 1.63 feet.
Mean deviation from center of impact, 2.40 feet.

RAPIDITY OF FIRE.

Twenty-one (21) trials were made to ascertain the number of rounds that could be fired per minute. The maximum was 2 and the minimum 0.63 rounds per minute, the gunners seeking shelter during each round, which caused a slight loss of time. These trials are given in Table IV.

JUMP.

The correction for the angles of elevation due to the use of the steel field-carriage was determined. The results of the observations are given in Table E.

TABLE E.—*Angle of jump.*

[*Date*: March 25, 1885. *Gun*: 3″.2 breech-loading rifle. *Carriage*: Steel field-carriage. *Projectile*: Solid-band experimental shell (new); weight, 13 pounds. *Powder*: DuPont LXA, D., 1.706; granulation, 270; weight of powder-charge, 8.5 pounds. *Distance of target from gun*: 50 feet. *Wind*: From rear, 11 miles per hour.]

Number of rounds.	Number of fire.	Elevation.	Recoil.	Angle of jump.	
		°	*Feet.*	′	″
1	618	0	9.75	20	00
2	619	0	9.75		
1	616	4	8.5	22	15
2	617	4	10.0		
1	614	8	8.0	23	15
2	615	8	8.0		
1	612	12	7.5	20	45
2	613	12	7.5		
1	610	16	7.0	17	07
2	611	16	8.0		
1	608	20	8.0	24	20
2	609	20	7.25		

OBTURATION AND BREECH MECHANISM.

The action of the interrupted screw and the two gas-checks, Freyre and De Bange, were very satisfactory. When once adjusted the Freyre check operated admirably. Both are very effective gas-checks. For details of their action see Table V. The number of rounds that have been fired with each gas-check is as follows:

	Rounds.
Freyre	704
De Bange	1096
Total	1800

ENDURANCE.

The Board decided, April 2, 1885, upon an endurance test of 800 rounds, but on May 1, 1885, after a correspondence between the Ordnance Board and the Chief of Ordnance, United States Army, in regard to the endurance test, the Board decided to fire one thousand additional rounds, making eighteen hundred rounds in all to which the gun has been subjected. After examination and star-gauging the gun was found to be still serviceable.

VENT.

Impressions were taken of the vent after the 800th, 854th, and 954th rounds. A new copper vent bushing was inserted after the 954th round. After the 1329th round the vent was found to be stopped by the upsetting of the copper bushing, and had to be drilled out.

Record of firing with 3.2-inch breech-loading rifle (steel) at Sandy

	Number of fire.	Time.	Powder. Kind.	Powder. Wgt. Pounds.	Powder. Wgt. Ounces.	Projectile. Kind.	Projectile. Wgt. Pounds.	Projectile. Wgt. Ounces.	Elevation.	Pressure per square inch of bore (crusher).	Instrumental velocity, 100 feet from muzzle.	Recoil.	Wind, strength and direction.
		1884.							° ′	*Lbs.*	*Feet.*	*Feet.*	
A. M.—Barometer, 30.401; thermometer, 42.8; humidity, 47.	245	Oct. 15	DuPont's I. K. D. Density, 1.725; granulation, 2200.	3	8	New.	13	..	—½	30,700	1,663	8.83	From rear and left, 8°; 17 miles an hour.
	246	Oct. 15		3	8		13	..	—½	......	.....	8.50	
	247	Oct. 15		3	8		13	..	—½	......	.....	8.83	
	248	Oct. 15		3	8		13	..	—½	......	.....	8.83	
	249	Oct. 15		3	8		13	..	—½	......	.....	8.83	
	250	Oct. 15		3	8		13	..	—½	......	.....	8.50	
A. M.—Barometer, 29.905; thermometer, 72.3; humidity, 52.	251	Oct. 22		3	8	Solid band experimental shell; band 3".30 diameter, 0".5 wide; beveled front and rear. Old.	13	..	—½	......	.....	8.50	From front and right, 45°; 22 miles an hour.
	252	Oct. 22		3	8		13	..	—½	......	.....	8.50	
	253	Oct. 22		3	8		13	..	—½	......	.....	8.50	
	254	Oct. 22		3	8		13	..	—½	......	.....	9.00	
	255	Oct. 22		3	8		13	..	—½	......	.....	9.50	
	256	Oct. 22		3	8		13	..	—½	......	.....	9.50	
	257	Oct. 22		3	8		13	..	—½	......	.....	9.00	
	258	Oct. 22		3	8		13	..	—½	......	.....	9.00	
	259	Oct. 22		3	8		13	..	—½	......	.....	9.00	
	260	Oct. 22		3	8		13	..	—½	......	.....	9.00	
	261	Oct. 22		3	8		13	..	—½	......	.....	9.00	
	262	Oct. 22		3	8		13	..	—½	......	.....	9.00	
	263	Oct. 22		3	8		13	..	—½	......	.....	9.00	
	264	Oct. 22		3	8		13	..	—½	......	.....	10.00	
	265	Oct. 22		3	8		13	..	—½	31,900	1,661	10.00	
	266	Oct. 22		3	8		13	..	—½	......	.....	9.00	
	267	Oct. 22		3	8		13	..	—½	......	.....	8.00	
	268	Oct. 22		3	8		13	..	—½	......	.....	9.00	
	269	Oct. 22		3	8		13	..	—½	......	.....	9.00	
	270	Oct. 22		3	8		13	..	—½	......	.....	9.00	
	271	Oct. 22		3	8		13	..	—½	......	.....	9.00	
	272	Oct. 22		3	8		13	..	—½	......	.....	8.50	
	273	Oct. 22		3	8		13	..	—½	......	.....	9.50	
	274	Oct. 22		3	8		13	..	—½	......	.....	8.50	
	275	Oct. 22		3	8		13	..	—½	......	.....	9.00	

After the 1054th round the gun was star-gauged while hot, and again after it became cold, to ascertain the amount of the enlargement due to the heat developed in firing. The table given below shows the enlargements with the gun hot and cold, together with the differences due to the heat:

Distance from the muzzle.	Enlargements of the bore after 1054th round with the gun.		
	Hot.	Cold.	Differences.
	Inch.	*Inch.*	*Inch.*
1 inch	0.010	0.005	0.005
10 inches	.013	.006	.007
26 inches	.014	.009	.005
36 inches	.016	.010	.006
46 inches	.018	.010	.008
56 inches	.018	.012	.006
60 inches	.018	.013	.005
65 inches	.021	.015	.006
70 inches	.023	.019	.004

ALTERATION OF MODEL.

The Board decided, on March 12 and April 2, 1885, to recommend certain alterations in the model. Subsequent to this action the details and outlines of the 3.2-inch steel breech-loading rifle were changed and settled by correspondence between the Ordnance Board and the Chief of Ordnance, United States Army; therefore no further action in regard to the subject has been taken or is necessary on the part of this Board.

OPINION.

The 3.2-inch breech-loading steel rifle has been "subjected to the proper test, including such rapid firing as a like gun would be likely to be subjected to in actual battle, for the determination of the endurance of the same," to the satisfaction of the Board.

RECOMMENDATION.

The Board would respectfully recommend that the 3.2-inch breech-loading steel rifle, or its modification, heretofore mentioned, as a suitable gun to "be put to use in the Government service."

T. G. BAYLOR,
Colonel of Ordnance, President of the Board.
F. H. PARKER,
Major of Ordnance.
GEO. W. McKEE,
Major of Ordnance.
CHARLES SHALER,
Captain of Ordnance.
D. A. LYLE,
Captain of Ordnance.

Record of firing with 3.2-inch breech-loading rifle (steel) at

	Number of fire.	Time.	Powder. Kind.	Powder. Wgt. Pounds.	Powder. Wgt. Ounces.	Projectile. Kind.	Projectile. Wgt. Pounds.	Projectile. Wgt. Ounces.	Elevation.	Pressure per square inch of bore (crusher).	Instrumental velocity, 100 feet from muzzle.	Recoil.	Wind, strength and direction.
		1884.							° ′	*Lbs.*	*Feet.*	*Feet.*	
A. M.—Barometer, 30.047; thermometer, 50.3; humidity, 85.	276	Nov. 1	DuPont's I. K. D. Density, 1.725; granulation, 2200.	3	8	Solid band experimental shell; 3″.30 diameter, 0″.5 wide; beveled front and rear. Old.	13	..	—¼	......	......	......	From front and right, 48°; 14 miles an hour.
	277	Nov. 1		3	8		13	..	—¼	......	......	......	
	278	Nov. 1		3	8		13	..	—¼	......	......	......	
	279	Nov. 1		3	8		13	..	—¼	......	......	......	
	280	Nov. 1		3	8		13	..	—¼	......	......	......	
	281	Nov. 1		3	8		13	..	—¼	......	......	......	
	282	Nov. 1		3	8		13	..	—¼	......	......	......	
	283	Nov. 1		3	8		13	..	—¼	......	......	......	
	284	Nov. 1		3	8		13	..	—¼	......	......	......	
	285	Nov. 1		3	8		13	..	—¼	......	......	......	
	286	Nov. 1		3	8		13	..	—¼	......	......	......	
	287	Nov. 1		3	8		13	..	—¼	......	......	......	
	288	Nov. 1		3	8		13	..	—¼	......	......	......	
	289	Nov. 1		3	8		13	..	—¼	......	......	......	
	290	Nov. 1		3	8		13	..	—¼	......	......	......	
	291	Nov. 1		3	8		13	..	—¼	......	......	......	
	292	Nov. 1		3	8		13	..	—¼	......	......	......	
	293	Nov. 1		3	8		13	..	—¼	......	......	......	
	294	Nov. 1		3	8		13	..	—¼	......	......	......	
	295	Nov. 1		3	8		13		—¼	......	......	......	
	296	Nov. 1		3	8		13	..	—¼	......	......	......	
	297	Nov. 1		3	8		13	..	—¼	......	......	......	
	298	Nov. 1		3	8		13	..	—¼	......	......	......	
	299	Nov. 1		3	8		13	..	—¼	......	......	......	
	300	Nov. 1		3	8		13	..	—¼	......	......	......	
	301	Nov. 1		3	8		13	..	—¼	......	......	......	
	302	Nov. 1		3	8		13	..	—¼	......	......	......	
	303	Nov. 1		3	8		13	..	—¼	......	......	......	
	304	Nov. 1		3	8		13	..	—¼	......	......	......	
	305	Nov. 1		3	8		13	..	—¼	......	......	......	
	306	Nov. 1		3	8		13	..	—¼	......	......	......	
	307	Nov. 1		3	8		13	.	—¼	......	......	......	
	308	Nov. 1		3	8		13	..	—¼	......	......	......	
	309	Nov. 1		3	8		13	..	—¼	......	......	......	
	310	Nov. 1		3	8		13	..	—¼	......	......	......	

Hook, N. J., from October 15, 1884, *to September* 15, 1885—Continued.

Special remarks about each fire, such as effect on piece, sound of projectile in flight, scattering of fragments, &c.
New steel cap, squares, and eye-bolts put on carriage.
Fired into sand-butt. De Bange gas-check. Rounds 276–315 inclusive fired for rapidity in 37½ minutes. Gun closed and opened easily. No escape of gas.

Record of firing with 3.2-inch breech-loading rifle (steel) at Sandy

	Number of fire.	Time.	Powder. Kind.	Powder. Wgt. Pounds.	Powder. Wgt. Ounces.	Projectile. Kind.	Projectile. Wgt. Pounds.	Projectile. Wgt. Ounces.	Elevation.	Pressure, per square inch of bore (crusher).	Instrumental velocity 100 feet from muzzle.	Recoil.	Wind, strength and direction.
		1885.							° ′	*Lbs.*	*Feet.*	*Feet.*	
A. M.—Barometer, 30.047; thermometer, 50.3; humidity, 85.	311	Nov. 1	DuPont's I. K. D. Density, 1.726; granulation, 2200.	3	8	Solid band experimental shell; 3″.3 diameter; 0″.5 wide; beveled front and rear. Old.	13	..	−¼	......	......	......	From front and right, 45°; 14 miles an hour.
	312	Nov. 1		3	8		13	..	−¼	......	......	......	
	313	Nov. 1		3	8		13	..	−¼	......	......	......	
	314	Nov. 1		3	8		13	..	−¼	......	......	......	
	315	Nov. 1		3	8		13	..	−¼	......	......	......	
	316	Nov. 1		3	8		13	..	−¼	......	......	......	
	317	Nov. 1		3	8		13	..	−¼	......	......	......	
	318	Nov. 1		3	8		13	..	−¼	......	......	......	
	319	Nov. 1		3	8		13	..	−¼	......	......	......	
	320	Nov. 1		3	8		13	..	−¼	......	......	......	
	321	Nov. 1		3	8		13	..	−¼	......	......	......	
	322	Nov. 1		3	8		13	..	−¼	......	......	......	
	323	Nov. 1		3	8		13	..	−¼	......	......	......	
	324	Nov. 1		3	8		13	..	−¼	......	......	......	
	325	Nov. 1		3	8		13	..	−¼	......	......	......	
	326	Nov. 1		3	8		13	..	−¼	......	......	......	
	327	Nov. 1		3	8		13	..	−¼	......	......	......	
	328	Nov. 1		3	8		13	..	−¼	......	......	......	
	329	Nov. 1		3	8		13	..	−¼	......	......	......	
	330	Nov. 1		3	8		13	..	−¼	......	......	......	
	331	Nov. 1		3	8		13	..	−¼	......	......	......	
	332	Nov. 1		3	8		13	..	−¼	......	......	......	
	333	Nov. 1		3	8		13	..	−¼	......	......	......	
	334	Nov. 1		3	8		13	..	−¼	......	......	......	
	335	Nov. 1		3	8		13	..	−¼	......	......	......	
	336	Nov. 1		3	8		13	..	−¼	......	......	......	
	337	Nov. 1		3	8		13	..	−¼	......	......	......	
	338	Nov. 1		3	8		13	..	−¼	......	......	......	
	339	Nov. 1		3	8		13	..	−¼	......	......	......	
	340	Nov. 1		3	8		13	..	−¼	......	......	......	
	341	Nov. 1		3	8		13	..	−¼	......	......	......	
	342	Nov. 1		3	8		13	..	−¼	......	......	......	
	343	Nov. 1		3	8		13	..	−¼	......	......	......	
	344	Nov. 1		3	8		13	..	−¼	......	......	......	
	345	Nov. 1		3	8		13	..	−¼	......	......	......	

Hook, N. J., from October 15, 1884, *to September* 15, 1885—Continued.

Special remarks about each fire, such as effect on piece, sound of projectile in flight, scattering of fragments, &c.
Washed out, examined, and star-gauged.
Fired into sand butt. De Bange gas-check. Gun closed and opened easily; no escape of gas.

Record of firing with 3.2-inch breech-loading rifle (steel) at Sandy

	Number of fire.	Time.	Powder. Kind.	Powder. Wgt. Pounds.	Powder. Wgt. Ounces.	Projectile. Kind.	Projectile. Wgt. Pounds.	Projectile. Wgt. Ounces.	Elevation.	Pressure per square inch of bore (Crusher).	Instrumental velocity 100 feet from muzzle.	Recoil.	Wind, strength and direction.
		1884.							° ′	*Lbs.*	*Feet.*	*Feet.*	
A. M.—Barometer, 30.047; thermometer, 50.3; humidity, 85.	346	Nov. 1	DuPont's I. K. D. Density, 1.725; granulation, 2200.	3	8	Solid band experimental shell; band, 3″.3 wide, diameter, 0″.5; beveled front and rear. (Old.)	13	..	—¼	......	....	.....	From front and right, 45°; 14 miles an hour.
	347	Nov. 1		3	8		13	..	—¼	......	....	.....	
	348	Nov. 1		3	8		13	..	—¼	......	....	.....	
	349	Nov. 1		3	8		13	..	—¼	......	....	....	
	350	Nov. 1		3	8		13	..	—¼	......	....	.....	
	351	Nov. 1		3	8		13	..	—¼	......	....	.....	
	352	Nov. 1		3	8		13	..	—¼	......	....	....	
	353	Nov. 1		3	8		13	..	—¼	......	....	....	
	354	Nov. 1		3	8		13	..	—¼	......	....	.....	
	355	Nov. 1		3	8		13	..	—¼	......	....	.....	
A. M.—Barometer, 30.081; thermometer, 37; humidity, 83.	356	Nov. 20		3	8		13	..	—¼	30,025	1,681	11.67	From rear and left, 3°; 8 miles an hour.
	357	Nov. 20		3	8		13	..	—¼	......	....	.....	
	358	Nov. 20		3	8		13	..	—¼	......	....	....	
	359	Nov. 20		3	8		13	..	—¼	......	....	.....	
	360	Nov. 20		3	8		13	..	—¼	......	....	.....	
	361	Nov. 20		3	8		13	..	—¼	......	....	....	
	362	Nov. 20		3	8		13	..	—¼	......	....	.....	
	363	Nov. 20		3	8		13	..	—¼	......	....	.....	
	364	Nov. 20		3	8		13	..	—¼	......	....	.....	
	365	Nov. 20		3	8		13	..	—¼	......	....	11.50	
	366	Nov. 20		3	8		13	..	—¼	......	....	....	
	367	Nov. 20		3	8		13	..	—¼	......	....	.....	
	368	Nov. 20		3	8		13	..	—¼	......	....	....	
	369	Nov. 20		3	8		13	..	—¼	......	....	.....	
	370	Nov. 20		3	8		13	..	—¼	......	....	.....	
	371	Nov. 20		3	8		13	..	—¼	......	....	....	
	372	Nov. 20		3	8		13	..	—¼	......	....	.....	
	373	Nov. 20		3	8		13	..	—¼	......	....	.....	
	374	Nov. 20		3	8		13	..	—¼	......	....	.....	
	375	Nov. 20		3	8		13	..	—¼	......	....	11.33	
	376	Nov. 20		3	8		13	..	—¼	......	....	.....	
	377	Nov. 20		3	8		13	..	—¼	......	....	.....	
	378	Nov. 20		3	8		13	..	—¼	......	....	.....	
	379	Nov. 20		3	8		13	..	—¼	......	....	.....	
	380	Nov. 20		3	8		13	..	—¼	......	....	.....	
	381	Nov. 20		3	8		13	..	—¼	......	....	.....	

TABLE III.—*Table of fires to obtain ranges at different elevations*—Continued.

ELEVATION OF 18 DEGREES.

Number of rounds.	Number of fire.	Date.	Recoil.	Time of flight.	Range.	Deflection.	
						Right.	Left.
		1885.	*Feet.*	*Seconds.*	*Yards.*	*Yards.*	*Yards.*
1	588	Mar. 24	8.25	22¼	6,150	....	31
2	589	Mar. 24	7.50	22¼	6,096	....	30.25
3	590	Mar. 24	8	22	6,090	....	30.50
4	591	Mar. 24	8	22¼	6,038	29	....
5	592	Mar. 24	8	21⅞	6,090	30.50	....
6	593	Mar. 25	8.50	22	6,155	58.50	....
7	594	Mar. 25	7.75	22¼	6,145	79.75	....
8	595	Mar. 25	7.75	21⅞	6,031	89.50	....
9	596	Mar. 25	7.25	22	6,064	79	....
10	597	Mar. 25	7.25	22	6,108	79.50	....
Mean	......	....	7.825	22	6,096.7	35.35	....

ELEVATION OF 20 DEGREES.

Number of rounds.	Number of fire.	Date.	Recoil.	Time of flight.	Range.	Right.	Left.
		1885.					
1	598	Mar. 25	7.5	24	6,456	89.25	....
2	599	Mar. 25	7	24	6,472	99.75	....
3	600	Mar. 25	7	24⅛	6,467	96.50	....
4	601	Mar. 25	7	24¼	6,506	101.50	....
5	602	Mar. 25	7	24¼	6,472	99.75	....
6	603	Mar. 25	6.75	Lost....	6,414	99.50	....
7	604	Mar. 25	7	23⅞	6,501	89.50	....
8	605	Mar. 25	6.75	24	6,564	101.75	....
9	606	Mar. 25	7	23⅞	6,491	89.50	....
10	607	Mar. 25	7	24	6,448	89	....
Mean	......	....	7	24 +	6,479.1	95.6	....

TABLE IV.—*Rapidity of fire. 3.2-inch breech-loading rifle.*

No. of trial.	Number of fire.		Total number rounds.	Time required for firing.	Number of rounds fired per minute.	Remarks.
	From rounds No.—	To rounds No.—				
				Minutes.		
1	276	315	40	37.5	1.06	
2	356	405	50	79	.63+	
3	710	748	39	50	.78	Gun being sponged out after each ten rounds.
4	767	800	34	50	.68	Including the interval after round 786 required to sponge out gun and replace bent elevating-screw by new one.
5	805	829	25	20	1.25	Gun cleaned out.
6	830	854	25	18	1.39	
7	855	879	25	23	1.08+	
8	880	904	25	23	1.08+	
9	905	954	50	40	1.25	
10	955	1054	100	90	1.11	Temperature of chase of gun near muzzle 374° F. at end of firing. Gun star-gauged while hot, and again when cold.
11	1055	1100	46	23	2.00	
12	1104	1167	64	60	1.06	
13	1209	1250	42	35	1.20	
14	1251	1300	50	45	1.11+	
15	1362	1386	25	18	1.39	
16	1389	1411	22	12	1.83+	
17	1412	1483	72	47	1.31+	
18	1487	1536	50	32	1.56+	
19	1537	1586	50	25	2.00	
20	1587	1636	50	28.5	1.75+	
21	1637	1686	50	45	1.11	

RÉSUMÉ.—*Number of rounds fired per minute.*

Maximum	2.00
Minimum	0.63
Mean	1.27

Record of firing with 3.2-inch breech-loading rifle (steel) at Sandy

	Number of fire.	Time.	Powder.			Projectile.			Elevation.	Pressure per square inch of bore (Crusher).	Instrumental velocity 100 feet from muzzle.	Recoil.	Wind, strength and direction.
			Kind.	Wgt. Pounds.	Wgt. Ounces.	Kind.	Wgt. Pounds.	Wgt. Ounces.					
		1884.							° ′	*Lbs.*	*Feet.*	*Feet.*	
A. M.—Barometer, 30.081; thermometer, 37; humidity, 83.	382	Nov. 20	DuPont's I. K. D. Density, 1.725; granulation, 2200.	3	8	Solid band experimental shell; band, 3″.3 diameter, 0″.5 wide; beveled front and rear. (Old.)	13	..	−½	......	......	......	From rear and left, 3°; 6 miles an hour.
	383	Nov. 20		3	8		13	..	−½	......	......	......	
	384	Nov. 20		3	8		13	..	−½	......	......	......	
	385	Nov. 20		3	8		13	..	−½	......	......	12.60	
	386	Nov. 20		3	8		13	..	−½	......	......	......	
	387	Nov. 20		3	8		13	..	−½	......	......	......	
	388	Nov. 20		3	8		13	..	−½	......	......	......	
	389	Nov. 20		3	8		13	..	−½	......	......	......	
	390	Nov. 20		3	8		13	..	−½	......	......	......	
	391	Nov. 20		3	8		13	..	−½	......	......	......	
	392	Nov. 20		3	8		13	..	−½	......	......	......	
	393	Nov. 20		3	8		13	..	−½	......	......	......	
	394	Nov. 20		3	8		13	..	−½	......	......	......	
	395	Nov. 20		3	8		13	..	−½	......	......	10.50	
	396	Nov. 20		3	8		13	..	−½	......	......	......	
	397	Nov. 20		3	8		13	..	−½	......	......	......	
	398	Nov. 20		3	8		13	..	−½	......	......	......	
	399	Nov. 20		3	8		13	..	−½	......	......	......	
	400	Nov. 20		3	8		13	..	−½	......	......	......	
	401	Nov. 20		3	8		13	..	−½	......	......	......	
	402	Nov. 20		3	8		13	..	−½	......	......	......	
	403	Nov. 20		3	8		13	..	−½	......	......	......	
	404	Nov. 20		3	8		13	..	−½	......	......	......	
	405	Nov. 20		3	8		13	..	−½	......	......	10.47	
P. M.—Barometer, 30.080; thermometer, 40.7; humidity, 77.	406	Nov. 20		3	8	Solid band experimental shell; 3″.30 diameter, 0″.5 wide; beveled front and rear. (Old.)	13	..	½	30,725	1,639	9.83	From rear and left, 3°; 10 miles an hour.
	407	Nov. 20		3	8		13	..	½	......	......	......	
	408	Nov. 20		3	8		13	..	½	......	......	......	
	409	Nov. 20		3	8		13	..	½	......	......	......	
	410	Nov. 20		3	8		13	..	½	......	......	......	
	411	Nov. 20		3	8		13	..	½	......	......	......	
	412	Nov. 20		3	8		13	..	½	......	......	......	
	413	Nov. 20		3	8		13	..	½	......	......	......	
	414	Nov. 20		3	8		13	..	½	......	......	......	
	415	Nov. 20		3	8		13	..	½	......	......	9.50	
	416	Nov. 20		3	8		13	..	½	......	......	......	
	417	Nov. 20		3	8		13	..	½	......	......	......	

Record of firing with 3.2-inch breech-loading rifle (steel) at Sandy

	Number of fire.	Time.	Powder. Kind.	Powder. Wgt. Pounds.	Powder. Wgt. Ounces.	Projectile. Kind.	Projectile. Wgt. Pounds.	Projectile. Wgt. Ounces.	Elevation.	Pressure per square inch of bore (crusher).	Instrumental velocity 100 feet from muzzle.	Recoil.	Wind, strength, and direction.
		1884.							° ′	*Lbs.*	*Feet.*	*Feet.*	
P. M.—Barometer, 30.080; thermometer, 40.7; humidity, 77.	418	Nov. 20	Du Pont's I. K. D. Density, 1.725; granulation, 2,200.	3	8	Solid band experimental shell; 3″.30 diameter, 0″.5 wide; beveled front and rear. Old.	13	..	½	.....	.....	.....	From rear and left, 8°; 10 miles an hour.
	419	Nov. 20		3	8		13	..	½	.....	.....	.....	
	420	Nov. 20		3	8		13	..	½	.....	.....	.....	
	421	Nov. 20		3	8		13	..	½	.....	.....	.....	
	422	Nov. 20		3	8		13	..	½	.....	.....	.....	
	423	Nov. 20		3	8		13	..	½	.....	.....	.....	
	424	Nov. 20		3	8		13	..	½	.....	.....	.....	
	425	Nov. 20		3	8		13	..	½	.....	.....	9.25	
	426	Nov. 20		3	8		13	..	½	.....	.....	.....	
	427	Nov. 20		3	8		13	..	½	.....	.....	.....	
	428	Nov. 20		3	8		13	..	½	.....	.....	.....	
	429	Nov. 20		3	8		13	..	½	.....	.....	.....	
	430	Nov. 20		3	8		13	..	½	.....	.....	.....	
	431	Nov. 20		3	8		13	..	½	.....	.....	.....	
	432	Nov. 20		3	8		13	..	½	.....	.....	.....	
	433	Nov. 20		3	8		13	..	½	.....	.....	.....	
	434	Nov. 20		3	8		13	..	½	.....	.....	.....	
	435	Nov. 20		3	8		13	..	½	.....	.....	9.50	
											128 feet from muzzle.		
	436	Nov. 20		3	8		13	..	½	.....	.....	.....	
	437	Nov. 20		3	8		13	..	½	.....	.....	.....	
	438	Nov. 20		3	8		13	..	½	.....	.....	.....	
	439	Nov. 20		3	8		13	..	½	.....	.....	.....	
	440	Nov. 20		3	8		13	..	½	.....	.....	.....	
	441	Nov. 20		3	8		13	..	½	.....	.....	.....	
	442	Nov. 20		3	8		13	..	½	.....	.....	.....	
	443	Nov. 20		3	8		13	..	½	.....	.....	.....	
	445	Nov. 20		3	8		13	..	½	.....	.....	.....	
	445	Nov. 20		3	8		13	..	½	.....	.....	.....	
	446	Nov. 20		3	8		13	..	½	.....	.....	.....	
	447	Nov. 20		3	8		13	..	½	.....	.....	.....	
	448	Nov. 20		3	8		13	..	½	.....	.....	.....	

Hook, N. J., from October 15, 1884, *to September* 15, 1885.

Special remarks about each fire, such as effect on piece, sound of projectile in flight, scattering of fragments, &c.
Gun mounted on iron carriage with stiffened cheeks (Watervliet Arsenal).
Opened and closed easily. No escape of gas.
Opened and closed little hard. No escape of gas.
Opened easily. Closed little hard. No escape of gas.
Gun washed out, examined, and star-gauged.

Fired into sand butt. De Bange gas-check.

Gun lashed to stock to prevent spring.

Cap-squares sprung and left front eye-bolt loosened.

Record of firing with 3.2-inch breech-loading rifle (steel) at Sandy

	Number of fire.	Time.	Powder. Kind.	Powder. Wgt. Pounds.	Powder. Wgt. Ounces.	Projectile. Kind.	Projectile. Wgt. Pounds.	Projectile. Wgt. Ounces.	Elevation.	Pressure per square inch of bore (crusher).	Instrumental velocity 128 feet from muzzle.	Recoil.	Wind, strength and direction.
		1884.							° ′	*Lbs.*	*Feet.*	*Feet.*	
P. M.—Barometer, 30.080; thermometer, 40.7; humidity, 77.	449	Nov. 20	DuPont's I. K. D. Density, 1.725; granulation, 2,200.	3	8	Solid band experimental shell; 3″.30 diameter; 0″.5 wide; beveled front and rear. (Old.)	13	..	½	.....	.....	.....	From rear and left, 8°, 10 miles an hour.
	450	Nov. 20		3	8		13	..	½	.....	.....	.....	
	451	Nov. 20		3	8		13	..	½	.....	.....	.....	
	452	Nov. 20		3	8		13	..	½	.....	.....	.....	
	453	Nov. 20		3	8		13	..	½	.....	.....	.....	
	454	Nov. 20		3	8		13	..	½	.....	.....	.....	
	455	Nov. 20		3	8		13	..	½	.....	.....	9.33	
P. M.—Barometer, 29.682; thermometer, 42.8; humidity, 50.	456	Nov. 26		3	8	With Hotchkiss base fuse, with sensitive fulminate.	13	..	2 35	.....	.....	6.75	From rear and right, 87°, 10 miles an hour.
	457	Nov. 26		3	8		13	..	2 35	.....	.....	6.25	
	458	Nov. 26		3	8		13	..	2 30	.....	.....	6.25	
	459	Nov. 26		3	8		13	..	2 30	.....	.....	6.50	
P. M.—Barometer, 30.315; thermometer, 56.3; humidity, 86.	460	Dec. 30	L.X DuPont's L. X. Density, 1.705; granulation, 270.	3	..	Solid band experimental shell; band, 3″.30 diameter; 0″.5 wide; beveled front and rear. Old.	13	..	0	25,200	1,511	12.00	From rear and right, 45°, 8 miles an hour.
	461	Dec. 30	L.X	3	8		13	..	0	30,000	1,[illegible]	12.[illegible]	

Hook, N. J., from October 15, 1884, *to September* 15, 1885—Continued.

Special remarks about each fire, such as effect on piece, sound of projectile in flight, scattering of fragments, &c.
New steel cap, squares, and eye-bolts put on carriage.
Fired into sand-butt. De Bange gas-check. Rounds 276–315 inclusive fired for rapidity in 37½ minutes. Gun closed and opened easily. No escape of gas.

Record of firing with 3.2-inch breech-loading rifle (steel) at

	Number of fire.	Time.	Powder. Kind.	Powder. Wgt. Pounds.	Powder. Wgt. Ounces.	Projectile. Kind.	Projectile. Wgt. Pounds.	Projectile. Wgt. Ounces.	Elevation.	Pressure, per square inch of bore (crusher).	Instrumental velocity 100 feet from muzzle.	Recoil.	Wind, strength and direction.
		1885.							° '	Lbs.	Feet.	Feet.	
A. M.—Barometer, 30.047; thermometer, 50.3; humidity, 85.	311	Nov. 1	DuPont's I. K. D. Density, 1.726; granulation, 2200.	3	8	Solid band experimental shell; 3".3 diameter; 0".5 wide; beveled front and rear. Old.	13	..	−½	......	......	......	From front and right, 45°; 14 miles an hour.
	312	Nov. 1		3	8		13	..	−½	......	......	......	
	313	Nov. 1		3	8		13	..	−½	......	......	......	
	314	Nov. 1		3	8		13	..	−½	......	......	......	
	315	Nov. 1		3	8		13	..	−½	......	......	......	
	316	Nov. 1		3	8		13	..	−½	......	......	......	
	317	Nov. 1		3	8		13	..	−½	......	......	......	
	318	Nov. 1		3	8		13	..	−½	......	......	......	
	319	Nov. 1		3	8		13	..	−½	......	......	......	
	320	Nov. 1		3	8		13	..	−½	......	......	......	
	321	Nov. 1		3	8		13	..	−½	......	......	......	
	322	Nov. 1		3	8		13	..	−½	......	......	......	
	323	Nov. 1		3	8		13	..	−½	......	......	......	
	324	Nov. 1		3	8		13	..	−½	......	......	......	
	325	Nov. 1		3	8		13	..	−½	......	......	......	
	326	Nov. 1		3	8		13	..	−½	......	......	......	
	327	Nov. 1		3	8		13	..	−½	......	......	......	
	328	Nov. 1		3	8		13	..	−½	......	......	......	
	329	Nov. 1		3	8		13	..	−½	......	......	......	
	330	Nov. 1		3	8		13	..	−½	......	......	......	
	331	Nov. 1		3	8		13	..	−½	......	......	......	
	332	Nov. 1		3	8		13	..	−½	......	......	......	
	333	Nov. 1		3	8		13	..	−½	......	......	......	
	334	Nov. 1		3	8		13	..	−½	......	......	......	
	335	Nov. 1		3	8		13	..	−½	......	......	......	
	336	Nov. 1		3	8		13	..	−½	......	......	......	
	337	Nov. 1		3	8		13	..	−½	......	......	......	
	338	Nov. 1		3	8		13	..	−½	......	......	......	
	339	Nov. 1		3	8		13	..	−½	......	......	......	
	340	Nov. 1		3	8		13	..	−½	......	......	......	
	341	Nov. 1		3	8		13	..	−½	......	......	......	
	342	Nov. 1		3	8		13	..	−½	......	......	......	
	343	Nov. 1		3	8		13	..	−½	......	......	......	
	344	Nov. 1		3	8		13	..	−½	......	......	......	
	345	Nov. 1		3	8		13	..	−½	......	......	......	

REPORT

Hook, N. J., from October 15,

Special remarks about each fire, such as effect on piece, s fragments, &c.

Washed out, examined, and star-gauged.

Fired into sand butt. De Bange gas-check. Gun closed and opened easily; no escape of gas.

Record of firing with 3.2-*inch breech-loading rifle (steel) at Sandy*

	Number of fire.	Time.	Powder. Kind.	Powder. Wgt. Pounds.	Powder. Wgt. Ounces.	Projectile. Kind.	Projectile. Wgt. Pounds.	Projectile. Wgt. Ounces.	Elevation.	Pressure per square inch of bore (Crusher).	Instrumental velocity 100 feet from muzzle.	Recoil.	Wind, strength and direction.
		1884.							° '	*Lbs.*	*Feet.*	*Feet.*	
A.M.—Barometer, 30.047; thermometer, 50.8; humidity, 85.	346	Nov. 1	DuPont's I. K. D. Density, 1.725; granulation, 2200.	3	8	Solid band experimental shell; band, 3".3 wide, diameter, 0".5; beveled front and rear. (Old.)	13	..	—½	......	......	......	From front and right, 45°; 14 miles an hour.
	347	Nov. 1		3	8		13	..	—½	......	......	......	
	348	Nov. 1		3	8		13	..	—½	......	......	......	
	349	Nov. 1		3	8		13	..	—½	......	......	......	
	350	Nov. 1		3	8		13	..	—½	......	......	......	
	351	Nov. 1		3	8		13	..	—½	......	......	......	
	352	Nov. 1		3	8		13		—½	......	......	......	
	353	Nov. 1		3	8		13	..	—½	......	......	......	
	354	Nov. 1		3	8		13	..	—½	......	......	......	
	355	Nov. 1		3	8		13	..	—½	......	......	......	
A.M.—Barometer, 30.081; thermometer, 37; humidity, 83.	356	Nov. 20		3	8		13	..	—½	30,025	1,631	11.67	From rear and left, 3°; 8 miles an hour.
	357	Nov. 20		3	8		13	..	—½	......	......	......	
	358	Nov. 20		3	8		13	..	—½	......	......	......	
	359	Nov. 20		3	8		13	..	—½	......	......	......	
	360	Nov. 20		3	8		13		—½	......	......	......	
	361	Nov. 20		3	8		13	..	—½	......	......	......	
	362	Nov. 20		3	8		13	..	—½	......	......	......	
	363	Nov. 20		3	8		13	..	—½	......	......	......	
	364	Nov. 20		3	8		13	..	—½	......	......	......	
	365	Nov. 20		3	8		13	..	—½	......	......	11.50	
	366	Nov. 20		3	8		13		—½	......	......	......	
	367	Nov. 20		3	8		13	..	—½	......	......	......	
	368	Nov. 20		3	8		13	..	—½	......	......	......	
	369	Nov. 20		3	8		13	..	—½	......	......	......	
	370	Nov. 20		3	8		13	..	—½	......	......	......	
	371	Nov. 20		3	8		13	..	—½	......	......	......	
	372	Nov. 20		3	8		13	..	—½	......	......	......	
	373	Nov. 20		3	8		13		—½	......	......	......	
	374	Nov. 20		3	8		13	..	—½	......	......	......	
	375	Nov. 20		3	8		13	..	—½	......	......	11.33	
	376	Nov. 20		3	8		13	..	—½	......	......	......	
	377	Nov. 20		3	8		13	..	—½	......	......	......	
	378	Nov. 20		3	8		13	..	—½	......	......	......	
	379	Nov. 20		3	8		13	..	—½	......	......	......	
	380	Nov. 20		3	8		13	..	—½	......	......	......	
	381	Nov. 20		3	8		13	..	—½	......	......	......	

Hook, N. J., from October 15, 1884, to September 15, 1885—Continued.

Special remarks about each fire, such as effect on piece, sound of projectile in flight, scattering of fragments, &c.
Fired into sand butt. De Bange gas-check. Rounds 316 to 355, inclusive, fired for rapidity in 42¼ minutes. There being no covering on asbestos of gas-check, asbestos squeezed out and spread over breech-block. Gun opened little hard during last 10 rounds; no escape of gas.
Gun washed out, examined, and star-gauged.
Fired into sand butt. De Bange gas-check covered with linen duck. A slight burr was formed on the rear copper band of mushroom head, which made closing rather difficult. No escape of gas.
Fired into sand butt. De Bange gas-check covered with linen duck. A slight burr was formed on the rear copper band of mushroom head, which made closing rather difficult. No escape of gas. Time of firing lot of 50, 1 hour and 19 minutes.

Record of firing with 3.2-inch breech-loading rifle (steel) at Sandy

	Number of fire.	Time.	Powder. Kind.	Powder. Wgt. Pounds.	Powder. Wgt. Ounces.	Projectile. Kind.	Projectile. Wgt. Pounds.	Projectile. Wgt. Ounces.	Elevation. ° ′	Pressure per square inch of bore (Crusher).	Instrumental velocity 100 feet from muzzle.	Recoil.	Wind, strength and direction.
		1884.								*Lbs.*	*Feet.*	*Feet.*	
A. M.—Barometer, 30.081; thermometer, 37; humidity, 83.	382	Nov. 20	DuPont's I. K. D. Density, 1.725; granulation, 2200.	3	8	Solid band experimental shell; band, 3″.3 diameter, 0″.5 wide; beveled front and rear. (Old.)	13	..	−½	----	----	----	From rear and left, 3°; 8 miles an hour.
	383	Nov. 20		3	8		13	..	−½	----	----	----	
	384	Nov. 20		3	8		13	..	−½	----	----	----	
	385	Nov. 20		3	8		13	..	−½	----	----	12.00	
	386	Nov. 20		3	8		13	..	−½	----	----	----	
	387	Nov. 20		3	8		13	..	−½	----	----	----	
	388	Nov. 20		3	8		13	..	−½	----	----	----	
	389	Nov. 20		3	8		13	..	−½	----	----	----	
	390	Nov. 20		3	8		13	..	−½	----	----	----	
	391	Nov. 20		3	8		13	..	−½	----	----	----	
	392	Nov. 20		3	8		13	..	−½	----	----	----	
	393	Nov. 20		3	8		13	..	−½	----	----	----	
	394	Nov. 20		3	8		13	..	−½	----	----	----	
	395	Nov. 20		3	8		13	..	−½	----	----	10.50	
	396	Nov. 20		3	8		13	..	−½	----	----	----	
	397	Nov. 20		3	8		13	..	−½	----	----	----	
	398	Nov. 20		3	8		13	..	−½	----	----	----	
	399	Nov. 20		3	8		13	..	−½	----	----	----	
	400	Nov. 20		3	8		13	..	−½	----	----	----	
	401	Nov. 20		3	8		13	..	−½	----	----	----	
	402	Nov. 20		3	8		13	..	−½	----	----	----	
	403	Nov. 20		3	8		13	..	−½	----	----	----	
	404	Nov. 20		3	8		13	..	−½	----	----	----	
	405	Nov. 20		3	8		13	..	−½	----	----	10.47	
P. M.—Barometer, 30.080; thermometer, 40.7; humidity, 77.	406	Nov. 20		3	8	Solid band experimental shell; 3″.30 diameter, 0″.5 wide; beveled front and rear. (Old.)	13	..	½	30,725	1,639	9.83	From rear and left, 3°; 10 miles an hour.
	407	Nov. 20		3	8		13	..	½	----	----	----	
	408	Nov. 20		3	8		13	..	½	----	----	----	
	409	Nov. 20		3	8		13	..	½	----	----	----	
	410	Nov. 20		3	8		13	..	½	----	----	----	
	411	Nov. 20		3	8		13	..	½	----	----	----	
	412	Nov. 20		3	8		13	..	½	----	----	----	
	413	Nov. 20		3	8		13	..	½	----	----	----	
	414	Nov. 20		3	8		13	..	½	----	----	----	
	415	Nov. 20		3	8		13	..	½	----	----	9.50	
	416	Nov. 20		3	8		13	..	½	----	----	----	
	417	Nov. 20		3	8		13	..	½	----	----	----	

Hook, N. J., from October 15, 1884, *to September* 15, 1885—Continued.

Special remarks about each fire, such as effect on piece, sound of projectile in flight, scattering of fragments, &c.

Fired into sand butt. De Bange gas-check covered with linen duck. A slight burr was formed on the rear copper band of mushroom head, which made closing rather difficult. No escape of gas. Time of firing lot of 50, 1 hour and 19 minutes.

Gun washed out, examined, and star-gauged.

Fired into sand butt. De Bange gas-check covered with linen duck. Closed and opened easily. No escape of gas.

Record of firing with 3.2-inch breech-loading rifle (steel) at Sandy

	Number of fire.	Time.	Powder.			Projectile.			Elevation.	Pressure per square inch of bore (crusher).	Instrumental velocity 100 feet from muzzle.	Recoil.	Wind, strength, and direction.
			Kind.	Wgt Pounds.	Wgt Ounces.	Kind.	Wgt Pounds.	Wgt Ounces.					
		1884.							° ′	*Lbs.*	*Feet.*	*Feet.*	
	418	Nov. 20	Du Pont's I. K. D. Density, 1.725; granulation, 2,200.	3	8	Solid band experimental shell; 3″.30 diameter, 0″.5 wide; beveled front and rear. Old.	13	..	½	......	......	......	From rear and left, 3°; 10 miles an hour.
	419	Nov. 20		3	8		13	..	½	......	......	......	
	420	Nov. 20		3	8		13	..	½	......	......	......	
	421	Nov. 20		3	8		13	..	½	......	......	......	
	422	Nov. 20		3	8		13	..	½	......	......	......	
	423	Nov. 20		3	8		13	..	½	......	......	......	
	424	Nov. 20		3	8		13	..	½	......	......	......	
	425	Nov. 20		3	8		13	..	½	......	......	9.25	
	426	Nov. 20		3	8		13	..	½	......	......	......	
	427	Nov. 20		3	8		13	..	½	......	......	......	
	428	Nov. 20		3	8		13	..	½	......	......	......	
	429	Nov. 20		3	8		13	..	½	......	......	......	
	430	Nov. 20		3	8		13	..	½	......	......	......	
	431	Nov. 20		3	8		13	..	½	......	......	......	
	432	Nov. 20		3	8		13	..	½	......	......	......	
	433	Nov. 20		3	8		13	..	½	......	......	......	
	434	Nov. 20		3	8		13	..	½	......	......	......	
P. M.—Barometer, 30.080; thermometer, 40.7; humidity, 77.	435	Nov. 20		3	8		13	..	½	......	......	9.50	
											128 feet from muzzle.		
	436	Nov. 20		3	8		13	..	½	......	......	......	
	437	Nov. 20		3	8		13	..	½	......	......	......	
	438	Nov. 20		3	8		13	..	½	......	......	......	
	439	Nov. 20		3	8		13	..	½	......	......	......	
	440	Nov. 20		3	8		13	..	½	......	......	......	
	441	Nov. 20		3	8		13	..	½	......	......	......	
	442	Nov. 20		3	8		13	..	½	......	......	......	
	443	Nov. 20		3	8		13	..	½	......	......	......	
	445	Nov. 20		3	8		13	..	½	......	......	......	
	445	Nov. 20		3	8		13	..	½	......	......	......	
	446	Nov. 20		3	8		13	..	½	......	......	......	
	447	Nov. 20		3	8		13	..	½	......	......	......	
	448	Nov. 20		3	8		13	..	½	......	......	......	

Hook, N. J., from October 15, 1884, *to September* 15, 1885—Continued.

Special remarks about each fire, such as effect on piece, sound of projectile in flight, scattering of fragments, &c.
Fired into sand butt. De Bange gas-check covered with linen duck. Closed and opened easily. No escape of gas.
Fired into sand butt. De Bange gas-check covered with linen duck. Total time firing lot of 50, 55 minutes. Closed and opened easily. No escape of gas.

Record of firing with 3.2-inch breech-loading rifle (steel) at Sandy

	Number of fire.	Time.	Powder.			Projectile.			Elevation.	Pressure per square inch of bore (crusher).	Instrumental velocity 128 feet from muzzle.	Recoil.	Wind, strength and direction.
			Kind.	Wgt Pounds.	Wgt Ounces.	Kind.	Wgt Pounds.	Wgt Ounces.					
		1884.							° ′	*Lbs.*	*Feet.*	*Feet.*	
P. M.—Barometer, 30.080; thermometer, 40.7; humidity, 77.	449	Nov. 20	DuPont's I. K. D. Density, 1.725; granulation, 2,200.	3	8	Solid band experimental shell; 3″.30 diameter; 0″.5 wide; beveled front and rear. (Old.)	13	..	½	......	......	......	From rear and left, 8°, 10 miles an hour.
	450	Nov. 20		3	8		13	..	½	......	......	......	
	451	Nov. 20		3	8		13	..	½	......	......	......	
	452	Nov. 20		3	8		13	..	½	......	......	......	
	453	Nov. 20		3	8		13	..	½	......	......	......	
	454	Nov. 20		3	8		13	..	½	......	......	......	
	455	Nov. 20		3	8		13	.	½	......	......	9.33	
P. M.—Barometer, 29.682; thermometer, 42.8; humidity, 50.	456	Nov. 26		3	8	With Hotchkiss base fuse, with sensitive fulminate.	13	..	2 35	......	......	6.75	From rear and right, 27°; 10 miles an hour.
	457	Nov. 26		3	8		13	..	2 35	......	......	6.25	
	458	Nov. 26		3	8		13	..	2 30	......	......	6.25	
	459	Nov. 26		3	8		13	..	2 30	......	......	6.50	
P. M.—Barometer, 30.315; thermometer, 56.3; humidity, 86.	460	Dec. 30	L.X DuPont's L.X. Density, 1.705; granulation, 270.	3	..	Solid band experimental shell; band, 3″.30 diameter; 0″.5 wide; beveled front and rear. Old.	13	..	0	25,200	1,511	12.00	From rear and right, 45°, 8 miles an hour.
	461	Dec. 30	L.X	3	8		13	..	0	[illegible]	[illegible]	[illegible]	

Hook, N. J., from October 15, 1884, *to September* 15, 1885—Continued.

		Special remarks about each fire, such as effect on piece, sound of projectile in flight, scattering of fragments, &c.
		Fired into sand butt. De Bange gas-check covered with linen duck. Total time firing lot of 50, 55 minutes. Closed and opened easily. No escape of gas.
		Gun washed out, examined, and star-gauged.
Fired at mile target.	Shells fired in rounds 456, 457, 458, and 459 contained a bursting charge of 6 ounces musket-powder. The weight of bursting-charge and fuse included in weight given to shell.	Burst on striking sand near target.
		Burst on striking sand to left of target.
		Burst on striking sand.
		Burst on striking sand.
		Fired into sand butt. De Bange gas-check covered with linen duck. Closed and opened easily. No escape of gas. Gun mounted on siege-carriage.

Record of firing with 3.2-inch breech-loading rifle (steel) at Sandy

	Number of fire.	Time.	Powder. Kind.	Powder. Wgt. Pounds.	Powder. Wgt. Ounces.	Projectile. Kind.	Projectile. Wgt. Pounds.	Projectile. Wgt. Ounces.	Elevation.	Pressure per square inch of bore (crusher).	Instrumental velocity 128 feet from muzzle.	Recoil.	Wind, strength and direction.
		1884.							° ′	*Lbs.*	*Feet.*	*Feet.*	
P. M.—Barometer, 30.315; thermometer, 56.3; humidity, 86.	462	Dec. 30	L.Y. Du Pont's. Density, 1.662; granulation, 270.	3	4	Solid band experimental shell; band 3″.30 diameter, 0″.5 wide; beveled front and rear. Old.	13	..	0	29,450	1,551	12.00	From rear and right, 45°, 8 miles an hour.
	463	Dec. 30	L.Y	3	8		13	..	0	33,400	1,615	12.00	
	464	Dec. 30	L.X Du Pont's L. X. Density 1.706; granulation 270.	3	8		13	..	0	31,300	1,617	11.00	
	465	Dec. 30	L.X	3	8		13	..	0	29,500	1,616	11.50	
	466	Dec. 30	L.X	3	8		13	..	0	32,100	1,627	12.00	
A. M.—Barometer, 30.043; thermometer, 54.4; humidity, 93.	467	Dec. 31	L.X	3	8	Solid band experimental shell, 3″.30 diameter, 0″.5 wide; beveled front and rear. Old.	13	..	0	33,100	1,631	8.00	From rear and right, 27°, 15 miles an hour.
	468	Dec. 31	L.X	3	8		13	..	0	29,500	1,617	8.00	
	469	Dec. 31	L.X	3	8		13	..	0	31,200	1,621	7.50	
	470	Dec. 31	L.X	3	8		13	..	0	31,400	1,634	8.00	
	471	Dec. 31	L.X	3	8		13	..	0	31,450	1,637	8.00	
	472	Dec. 31	L.X	3	8		13	..	0	30,000	1,627	7.50	
		1885.									128 feet from muzzle.		
P. M.—Barometer, 30.006; thermometer, 42; humidity, 86.	473	Jan. 8	Du Pont's I. K. D. Density, 1.725; granulation, 2,200.	3	8		13	..	—¼	28,350	1,588	7.00	From rear and right, 27°, 10 miles an hour.
	474	Jan. 8		3	8		13	..	—¼	......	......	......	
	475	Jan. 8		3	8		13	..	—¼	......	......	......	
	476	Jan. 8		3	8		13	..	—¼	......	......	......	
	477	Jan. 8		3	8		13	..	—¼	......	......	......	

Hook, N. J., from October 15, 1884, *to September* 15, 1885—Continued.

Special remarks about each fire, such as effect on piece, sound of projectile in flight, scattering of fragments, &c.
Fired into sand butt. De Bange gas-check covered with linen duck. Closed and opened easily. No escape of gas. Gun mounted on siege-carriage.
Trail broke.
Gun mounted on iron carriage.
Fired into sand butt. De Bange gas-check covered with linen duck. Closed and opened easily. No escape of gas.
Fired into sand butt. De Bange gas-check covered with asbestus cloth. Closed and opened easily. No escape of gas.

Record of firing with 3.2-inch breech-loading rifle (steel) at Sandy

	Number of fire.	Time.	Powder. Kind.	Powder. Wgt. Pounds.	Powder. Wgt. Ounces.	Projectile. Kind.	Projectile. Wgt. Pounds.	Projectile. Wgt. Ounces.	Elevation.	Pressure per square inch of bore (Crusher).	Instrumental velocity 128 feet from muzzle.	Recoil.	Wind, strength and direction.
		1885.							° ′	Lbs.	Feet.	Feet.	
P. M.—Barometer, 30.006; thermometer, 42; humidity, 86.	478	Jan 8	DuPont's I. K. D. Density, 1.725; granulation, 2,200.	3	8	Solid band experimental shell, 3″.30 diameter, 0″.5 wide; beveled front and rear. (Old.)	13	..	—½	......	....	....	From rear and right, 87°; 16 miles an hour.
	479	Jan. 8		3	8		13	..	—½	......	....	....	
	480	Jan. 8		3	8		13	..	—½	......	....	7.50	
	481	Jan. 8		3	8		13	..	—½	......	....	....	
	482	Jan. 8		3	8		13	..	—½	......	....	....	
A. M.—Barometer, 29.789; thermometer, 46.3; humidity, 35.4.	483	Jan. 9		3	8		13	..	—½	......	....	....	From rear and right, 87°; 14 miles an hour.
	484	Jan. 9		3	8		13	..	—½	......	....	....	
	485	Jan. 9		3	8		13	..	—½	......	....	....	
	486	Jan. 9		3	8		13	..	—½	......	....	....	
	487	Jan. 9		3	8		13	..	—½	......	....	....	
	488	Jan 9		3	8		12	..	—½	......	....	....	
	489	Jan. 9		3	8		13	..	—½	......	....	....	
	490	Jan. 9		3	8		13	..	—½	......	....	....	
	491	Jan. 9		3	8		13	..	—½	......	....	....	
	492	Jan. 9		3	8		13	..	—½	......	....	....	
	493	Jan. 9		3	8		13	..	—½	......	....	....	
	494	Jan. 9		3	8		13	..	—½	......	....	....	
	495	Jan. 9		3	8		13	..	—½	......	....	....	
	496	Jan. 9		3	8		13	..	—½	......	....	....	
	497	Jan. 9		3	8		13	..	—½	......	....	....	
	498	Jan. 9		3	8		13	..	—½	......	....	....	
	499	Jan. 9		3	8		13	..	—½	......	....	....	
	500	Jan. 9		3	8		13	..	—½	......	....	8.00	
											107 feet from muzzle.		
A. M.—Barometer, 30.093; thermometer, 20.9; humidity, 65.	501	Mar. 18	DuPont's L. X. A. Density, 1.700; granulation, 270.	3	8	Solid band experimental shell; band 3″.30 diameter, 0″.5 wide; beveled front and rear.	13	..	0	29,300	1,572	10.00	From front and left, 87°; 10 miles an hour.
	502	Mar. 18		3	8		13	..	0	30,525	1,592	10.00	
	503	Mar. 18		3	8		13	..	0	28,800	1,579	10.00	
	504	Mar. 18		3	8		13	..	0	28,450	1,575	10.00	
	505	Mar. 18		3	8		13	..	0	28,000	1,585	10.90	
	506	Mar. 18		3	8		13	..	0	28,500	1,580	10.00	

Hook, N. J., from October 15, 1884, *to September* 15, 1885—Continued.

Special remarks about each fire, such as effect on piece, sound of projectile in flight, scattering of fragments, &c.

Fired into sand butt. De Bange gas-check covered with asbestos cloth. Closed and opened easily. No escape of gas.

Right brake broke; repaired.

	Ranges.	Deflection.	
	Yds.	*Yards.*	**Steel carriage previously used and recently repaired at Watervliet Arsenal.**
......	......	....	**Fired into sand-butt to try powder.**
......	......	....	**Hook of left-hand brake broken off.**
......	......	....	**Left brake (belonging to old carriage) jumped off.**
......	......	....	
......	......	....	
......	......	....	**Hook of right-hand brake broken off.**

Record of firing with 3.2-inch breech-loading rifle (steel; at Sandy

	Number of fire.	Time.	Powder. Kind.	Powder. Wgt. Pounds.	Powder. Wgt. Ounces.	Projectile. Kind.	Projectile. Wgt. Pounds.	Projectile. Wgt. Ounces.	Elevation.	Pressure per square inch of bore (crusher).	Instrumental velocity 107 feet from muzzle.	Recoil.	Wind, strength and direction.
		1885.							° '	Lbs.	Feet.	Feet.	
A. M.—Barometer, 30.093; thermometer, 20.9; humidity, 65.	507	Mar. 18	Du Pont's L. X. A. Density, 1.706; granulation, 270.	3	8	Solid band experimental shell; band 3".30 diameter, 0".5 wide; beveled front and rear.	13	..	2	......	.....	9.00	From front and left, 32°, 9 miles an hour.
	508	Mar. 18		3	8		13	..	2	......	....	9.00	
	509	Mar. 18		3	8		13	..	2	......	.....	10.00	
	510	Mar. 18		3	8		13	..	2	......	.....	10.00	
	511	Mar. 18		3	8		13	..	2	......	.....	10.00	
	512	Mar. 18		3	8		13	..	2	......	.....	10.00	
	513	Mar. 18		3	8		13	..	2	......	.....	10.00	
	514	Mar. 18		3	8		13	..	2	......	.....	10.00	
	515	Mar. 18		3	8		13	..	2	......	....	10.00	
	516	Mar. 18		3	8		13	..	2	......	.....	10.00	
P. M.—Barometer, 29.974; thermometer, 25; humidity, 66.	517	Mar. 18		3	8		13	..	4	......	.....	12.00	From front; 6 miles an hour.
	518	Mar. 18		3	8		13	..	4	......	....	9.00	
	519	Mar. 18		3	8		13	..	4	......	.....	9.50	
	520	Mar. 18		3	8		13	..	4	.....	....	9.50	
	521	Mar. 18		3	8		13	..	4	......	....	9.50	
	522	Mar. 18		3	8		13	..	4	......	....	9.50	
	523	Mar. 18		3	8		13	..	4	......	....	9.50	
	524	Mar. 18		3	8		13	..	4	......	.....	9.00	
	525	Mar. 18		3	8		13	..	4	......	.....	9.50	
	526	Mar. 18		3	8		13	.	4	......	....	.....	
A. M.—Barometer, 29.726; thermometer, 26; humidity, 78.	527	Mar. 19		3	8		13	..	6	......	....	8.50	From front and left, 30°; 6 miles an hour.
	528	Mar. 19		3	8		13	..	6	......	....	8.50	
	529	Mar. 19		3	8		13	..	6	......	..	8.50	
	530	Mar. 19		3	8		13	..	6	......	.....	8.50	
	531	Mar. 19		3	8		13	..	6	......	.....	8.50	
	532	Mar. 19		3	8		13	..	6	......	.....	8.50	
	533	Mar. 19		3	8		13	..	6	......	.....	8.50	
	534	Mar. 19		3	8		13	..	6	......	.....	8.50	
	535	Mar. 19		3	8		13	..	6	......	.....	8.50	
	536	Mar. 19		3	8		13	..	6	......	.....	8.50	
	537	Mar. 19		3	8		13	..	8	......	.....	8.00	
	538	Mar. 19		3	8		13	..	8	......	.....	8.25	
	539	Mar. 19		3	8		13	..	8	......	.....	8.00	
	540	Mar. 19		3	8		13	..	8	......	.....	8.00	
	541	Mar. 19		3	8		13	..	8	......	.....	8.00	
	542	Mar. 19		3	8		13	..	8	......	.....	8.00	

k, *N. J.*, *from October*, 15, 1884, *to September* 15, 1885—Continued.

	Ranges.	Deflection.	Special remarks about each fire, such as effect on piece, sound of projectile in flight, scattering of fragments, &c.
	Yds.	*Yards.*	
	1,578	⅛ right	Fired over water for ranges. De Bange gas-check. Gun opened and closed easily after small burr on copper ring had been removed. No escape of gas. Axis of gun 14.3 feet above sea-level.
	1,595	⅛ right	
⅛	1,589	⅛ right	
⅛	1,566	1⅛ left	
	1,584	2¾ left	
	1,600	½ right	
	1,571	¾ right	
	1,578	⅛ right	
	1,580	0	
	1,608	1½ left	
¾	2,370	0	Axis of gun 16.6 feet above sea-level. Right hand brake broken off at shank.
¼	2,363	0	New brakes put on.
½	2,361	2⅛ right	
¾	2,365	0	
⅝	2,359	2¾ right	
6⅛	2,350	2¾ right	Left hand brake broke.
6⅛	2,376	2½ right	Right hand brake broke at hook.
6⅛	2,370	2⅛ right	Repaired brakes put on.
6⅛	2,371	2⅛ right	Right hand brake broke.
6⅛	2,348	½ left	No brakes on carriage.
9	3,037	1⅛ left	Axis of gun 12 feet above sea-level
9	3,038	1⅛ left	
9	3,030	0	
9⅛	3,045	1½ left	
9	3,054	1½ left	
9⅛	3,043	0	
9	3,042	0	
9⅛	3,028	0	
9	3,022	0	
8⅞	3,024	1⅛ left	
11⅞	3,633	7 right	Axis of gun 12.9 feet above sea-level.
11⅛	3,638	7 right	
11⅛	3,634	7 right	Rivet of transom of trail-chest broke.
11⅞	3,632	7 right	Hinge for trail-chest broke.
11⅛	3,643	6 right	
11⅞	3,621	8 right	

Record of firing with 3.2-inch breech-loading rifle (steel) at [illegible]

	Number of fire.	Time.	Powder. Kind.	Powder. Wgt. Pounds.	Powder. Wgt. Ounces.	Projectile. Kind.	Projectile. Wgt. Pounds.	Projectile. Wgt. Ounces.	Elevation.	Pressure, per square inch of bore (crusher).	Instrumental velocity 107 feet from muzzle.	Recoil.	Wind, strength and direction.
		1885.							° ′	*Lbs.*	*Feet.*	*Feet.*	
A. M.—Barometer, 29.726; thermometer, 26; humidity, 78.	543	Mar. 19	Du Pont's L. X. A. Density, 1.706; granulation, 270.	3	8	Solid band experimental shell. Band, 3″.3 diameter, 0″.5 wide; beveled front and rear.	13	..	8	......	......	8.00	From front and left, 35°; 6 miles an hour.
	544	Mar. 19		3	8		13	..	8	......	......	8.00	
	545	Mar. 19		3	8		13	..	8	......	......	8.25	
	546	Mar. 19		3	8		13	..	8	......	......	8.25	
	547	Mar. 19		3	8		13	..	10	......	......	7.75	
	548	Mar. 19		3	8		13	..	10	......	......	8.00	
	549	Mar. 19		3	8		13	..	10	......	......	7.75	
	550	Mar. 19		3	8		13	..	10	......	......	8.25	
	551	Mar. 19		3	8		13	..	10	......	......	8.00	
	552	Mar. 19		3	8		13	..	10	......	......	8.00	
	553	Mar. 19		3	8		13	..	10	......	......	8.25	
	554	Mar. 19		3	8		13	..	10	......	......	8.25	
	555	Mar. 19		3	8		13	..	10	......	......	8.50	
	556	Mar. 19		3	8		13	..	10	......	......	8.50	
	557	Mar. 19		3	8		13	..	12	......	......	8.50	
P. M.—Barometer, 30.242; thermometer, 37.7; humidity, 44.	558	Mar. 24		3	8		13	..	12	......	......	8.00	From rear and right, 30°; 30 miles an hour.
	559	Mar. 24		3	8		13	..	12	......	......	7.50	
	560	Mar. 24		3	8		13	..	12	......	......	8.00	
	561	Mar. 24		3	8		13	..	12	......	......	8.00	
	562	Mar. 24		3	8		13	..	12	......	......	8.00	
	563	Mar. 24		3	8		13	..	12	......	......	8.00	
	564	Mar. 24		3	8		13	..	12	......	......	8.00	
	565	Mar. 24		3	8		13	..	12	......	......	8.50	
	566	Mar. 24		3	8		13	..	12	......	......	8.25	
	567	Mar. 24		3	8		13	..	12	......	......	8.50	
	568	Mar. 24		3	8	Solid band experimental shell; band 3″.3 diameter, 0″.5 wide; beveled front and rear. (New.)	13	..	14	......	......	8.25	
	569	Mar. 24		3	8		13	..	14	......	......	8.00	
	570	Mar. 24		3	8		13	..	14	......	......	8.00	
	571	Mar. 24		3	8		13	..	14	......	......	8.25	
	572	Mar. 24		3	8		13	..	14	......	......	8.00	
	573	Mar. 24		3	8		13	..	14	......	......	7.75	
	574	Mar. 24		3	8		13	..	14	......	......	7.75	
	575	Mar. 24		3	8		13	..	14	......	......	8.00	
	576	Mar. 24		3	6		13	..	14	......	......	8.00	
	577	Mar. 24		3	8		13	..	14	......	......	8.00	

Hook, N. J., from October 15, 1884, *to September* 15, 1885—Continued.

Time of flight.	Ranges.	Deflection.	Special remarks about each fire, such as effect on piece, sound of projectile in flight, scattering of fragments, &c.
Secs.	*Yds.*	*Yards.*	
11⅛	3,653	6 right	Fired over water for ranges. De Bange gas-check. Gun opened and closed easily after small burr on copper ring had been removed. No escape of gas. Axis of gun 12.9 feet above sea-level.
11⅛	3,642	6⅛ right	
11⅛	3,643	6⅛ right	
11⅜	3,622	8 right	
13⅛	4,165	12¼ right	Axis of gun 12.7 feet above sea-level.
14	4,166	12¼ right	
13⅝	4,156	13 right	
13⅛	4,128	18 right	
13⅜	4,143	17⅛ right	
13⅞	4,163	12 right	
13⅝	4 155	12⅛ right	
13¾	4,155	17¼ right	
13¼	4,128	18 right	
14	4,144	17⅛ right	
Lost	......	....	
15⅛	4,789	48¾ left	Axis of gun 13.2 feet above sea-level.
15⅛	4,813	49¼ left	
15¾	4,853	45¾ left	
15¾	4,839	45⅛ left	
15¾	4,838	45⅛ left	
15⅞	4,832	45¼ left	
15¾	4,847	45 left	
15⅝	4,790	44 left	
15⅝	4,801	49¼ left	
15⅞	4,838	45⅛ left	
17⅞	5,268	37½ left	Axis of gun 13.7 feet above sea-level.
18	5,314	29⅛ left	
17¾	5,248	29 left	
18	5,285	29¼ left	
18	5,285	29½ left	
17⅞	5,284	29¼ left	
17⅞	5,248	29 left	
17⅞	5,224	28 left	
18	5,208	37⅛ left	
17⅞	5,251	37½ left	

Record of firing with 3.2-inch breech-loading rifle (steel) at Sandy

	Number of fire.	Time.	Powder. Kind.	Powder. Wgt. Pounds.	Powder. Wgt. Ounces.	Projectile. Kind.	Projectile. Wgt. Pounds.	Projectile. Wgt. Ounces.	Elevation.	Pressure per square inch of bore (crusher).	Instrumental velocity 107 feet from muzzle.	Recoil.	Wind, strength and direction.
		1885.							° ′	*Lbs.*	*Feet.*	*Feet.*	
P. M.—Barometer, 30.242; thermometer, 37.7; humidity, 44.	578	Mar. 24	Du Pont's L. X. A. Density, 1.706; granulation, 270.	3	8	Solid band experimental shell; band 3″.3 diameter, 0″.5 wide; beveled front and rear. (New.)	13	..	16	......	.....	8.25	From rear and right, 30°; 20 miles an hour.
	579	Mar. 24		3	8		13	..	16	......	.....	8.00	
	580	Mar. 24		3	8		13	..	16	......	.....	7.75	
	581	Mar. 24		3	8		13	..	16	......	.....	8.00	
	582	Mar. 24		3	8		13	..	16	......	.....	8.25	
	583	Mar. 24		3	8		13	..	16	......	.....	8.50	
	584	Mar. 24		3	8		13	..	16	......	.....	8.25	
	585	Mar. 24		3	8		13	..	16	......	.....	8.25	
	586	Mar. 24		3	8		13	..	16	......	.....	8.00	
	587	Mar. 24		3	8		13	..	16	......	.....	8.33	
	588	Mar. 24		3	8		13	..	18	......	.....	8.25	
	589	Mar. 24		3	8		13	..	18	......	.....	7.50	
	590	Mar. 24		3	8		13	..	18	......	.....	8.00	
	591	Mar. 24		3	8		13	..	18	......	.....	8.00	
	592	Mar. 24		3	8		13	..	18	......	.....	8.00	
P. M.—Barometer, 30.200; thermometer, 38.1; humidity, 46.	593	Mar. 25		3	8		13	..	18	......	.....	8.50	From rear; 11 miles an hour.
	594	Mar. 25		3	8		13	..	18	......	.....	7.75	
	595	Mar. 25		3	8		13		18	......	.....	7.75	
	596	Mar. 25		3	8		13	..	18	......	.....	7.25	
	597	Mar. 25		3	8		13	..	18	......	.....	7.25	
	598	Mar. 25		3	8		13	..	20	......	.....	7.50	
	599	Mar. 25		3	8		13	..	20	......	.....	7.00	
	600	Mar. 25		3	8		13	..	20	......	.....	7.00	
	601	Mar. 25		3	8		13	..	20	......	.....	7.00	
	602	Mar. 25		3	8		13	..	20	......	.....	7.00	
	603	Mar. 25		3	8		13	..	20	......	.....	6.75	
	604	Mar. 25		3	8		13		20	......	.....	7.00	
	605	Mar. 25		3	8		13	..	20	......	.....	8.75	
	606	Mar. 25		3	8		13	..	20	......	.....	7.00	
	607	Mar. 25		3	8		13	..	20	......	.....	7.00	
	608	Mar. 25		3	8		13	..	20	......	.....	8.00	
	609	Mar. 25		3	8		13	..	20	......	.....	7.25	
	610	Mar. 25		3	8		13	..	16	......	.....	7.00	
	611	Mar. 25		3	8		13		16	......	.....	8.00	
	612	Mar. 25		3	8		13	..	12	......	.....	7.50	
	613	Mar. 25		3	8		13	..	12	......	.....	7.50	

N. J., from October 15, 1884, *to September* 15, 1885—**Continued.**

Angle of jump.	Ranges.	Deflection.	Special remarks about each fi jectile in flight, s
′ ″	*Yds.*	*Yards.*	
......	5,70?	23½ left	Fired over water for ranges. De Range gas-check. Axis of gun 13.9 feet above sea-level.
......	5,708	23½ left	
......	5,671	23¼ left	
......	5,698	23½ left	
......	5,684	38 left	
......	5,702	38¼ left	
......	5,671	23¼ left	
......	5,716	38¼ left	
......	5,684	38 left	
......	5,667	23 left	
......	6,150	31 left	Axis of gun 14.2 feet above sea-level.
......	6,096	30¾ left	
......	6,090	30½ left	
......	6,038	29 right	
......	6,090	30½ right	
......	6,155	58½ right	Axis of gun 13.2 feet above sea-level.
......	6,145	79¾ right	
......	6,031	89½ right	
......	6,064	79 right	
......	6,108	79½ right	
......	6,456	89¼ right	Axis of gun 12.8 feet above sea-level.
......	6,472	99¾ right	
......	6,467	96½ right	
......	6,506	101½ right	
......	6,472	99¾ right	
......	6,414	99½ right	
......	6,501	89½ right	Block stuck in carrier-ring-screw for catch.
......	6,564	101¾ right	
......	6,491	89½ right	During this firing all the small rivets for tran chest on left side broke off, as well as right ri
......	6,448	89 right	
24 20			Fired at target 50 feet from gun to ascertain angle of jump.
17 7			
20 45			

Record of firing with 3.2-inch breech-loading rifle (steel) at Sandy

	Number of fire.	Time.	Powder. Kind.	Powder. Wgt. Pounds.	Powder. Wgt. Ounces.	Projectile. Kind.	Projectile. Wgt. Pounds.	Projectile. Wgt. Ounces.	Elevation.	Pressure per square inch of bore (crusher).	Instrumental velocity 100 feet from muzzle.	Recoil.	Wind, strength and direction.
		1885.							° '	*Lbs.*	*Feet.*	*Feet*	
P. M.—Barometer, 30.200; thermometer, 38.1; humidity, 46.	614	Mar. 25	Du Pont's L. X. A. Density, 1.706; granulation, 270.	3	8	Solid band experimental shell; band 3''.3 diameter, 0''.5 wide; beveled front and rear. (New.)	13	..	8	......	....	8.00	From rear; 11 miles an hour.
	615	Mar. 25		3	8		13	..	8	......	....	8.00	
	616	Mar. 25		3	8		13	..	4	......	....	8.50	
	617	Mar. 25		3	8		13	..	4	......	....	10.00	
	618	Mar. 25		3	8		13	..	0	......	....	9.75	
	619	Mar. 25		3	8		13		0	......	....	9.75	
P. M.—Barometer, 30.169; thermometer, 46.8; humidity, 42.	620	Mar. 26		3	8		13	.	2 20	......	1,581	9.50	From front and right 8°; 24 miles an hour.
	621	Mar. 26		3	8		13	..	2 20	......	1,591	4.67	
A. M.—Barometer, 29.975; thermometer, 44.5; humidity, 74.6.	622	Mar. 27		3	8		13	..	2 18	......	1,617	2.58	From rear and right 87°; 8 miles an hour.
	623	Mar. 27		3	8		13	..	2 20	......	1,590	4.33	
Barometer, 29.979; thermometer, 42.2; humidity, 65. A.M.	624	Mar. 28	Du Pont's I. K. D. Density 1.725; granulation, 2,200.	3	8		13	..	2 25	...	1,641	3.67	From rear; 9 miles an hour.
A.M.	625	Mar. 28		3	8		13	..	2 30	......	1,619	3.33	
P. M.	626	Mar. 28		3	8		13	..	2 30	......	1,615	3.25	
P. M.—Barometer, 30.189; thermometer, 57.9; humidity, 42.	627	Apr. 1	Du Pont's L. X. A. Density 1.706; granulation 270.	3	8		13	..	2 30	......	1,583	3.00	
	628	Apr. 1		3	8		13	..	2 35	......	1,612	3.50	From rear and right 87°; 13 miles an hour.
	629	Apr. 1		3	8		13	.	2 35	......	1,589	3.23	
	630	Apr. 1		3	8		13		2 35	......	1,586	3.42	
	631	Apr. 1		3	8		13	..	2 35	....	1,596	3.00	
	632	Apr. 1		3	8		13	.	2 35	......	1,587	3.50	
	633	Apr. 1		3	8		13	..	2 35	......	1,600	3.47	14 miles an hour.
	634	Apr. 1		3	8		13	..	2 35	......	1,586	3.16	
	635	Apr. 1		3	8		13	..	2 35	......	1,601	3.00	
	636	Apr. 1		3	8		13	..	2 35	......	1,591	3.72	

Hook, N. J., from October 15, 1884, *to September* 15, 1885—Continued.

Time of flight.	Angle of jump.	Special remarks about each fire, such as effect on piece, sound of projectile in flight, scattering of fragments, &c.
Sec'ds	′ ″	
......	23 15	Fired at target 50 feet from gun to ascertain angle of jump.
......		
......	22 15	
......		
......	20 0	
......		

Gun mounted on 30-pounder Parrott carriage.

Fired at mile target. Sighting shots.

Fired at mile target. Sighting shot.

Distance from center of target in feet.				Distance from center of impact in feet.				
Vertical.		Horizontal.		Vertical.		Horizontal.		
Above.	Below.	Right.	Left.	Above.	Below.	Right.	Left.	
....	0. 50	....	11. 00	1. 63	....	....	6. 47	Fired at mile target. Target 20′ × 40′, made of 1″ spruce boards. Axis of gun 5 8 feet above bull's-eye of target.
....	5. 00	1 68	....	....	2. 87	6. 21	....	
	Under target.							
....	4. 34	....	5. 75	....	2. 21	....	1. 22	
....	5. 00	....	3. 00	....	2. 87	1. 53	....	
....	1. 34	....	9. 00	0. 79	....	....	4. 47	
....	0. 18	....	1. 00	1. 95	....	3. 53	....	
0. 32	....	....	8. 00	2. 45	....	1. 53	....	
....	1. 00	....	5. 17	1. 13	....	....	0. 64	
0. 32	17. 36	1. 68	37. 92	7. 95	7. 95	12. 80	12. 80	
17. 04 + 8=2. 13		36. 24 + 8=4. 53		15. 90 + 8=1. 99		25. 60 + 8=3. 20		

Mean vertical deviation from center of impact, 1.99 feet.

Mean horizontal deviation from center of impact, 3.20 feet.

Mean deviation from center of impact, 3.77 feet.

Record of firing with 3.2-inch breech-loading rifle (steel) at Sandy

	Number of fire.	Time.	Powder. Kind.	Powder. Wgt. Pounds.	Powder. Wgt. Ounces.	Projectile. Kind.	Projectile. Wgt. Pounds.	Projectile. Wgt. Ounces.	Elevation.	Pressure per square inch of bore (crusher).	Instrumental velocity 100 feet from muzzle.	Recoil.	Wind, strength and direction.
		1885.							° ′	*Lbs.*	*Feet*	*Feet*	
P. M.—Barometer, 30.265; thermometer, 40.7; humidity, 76.	637	Apr. 2	DuPont's I. K. D. Density 1.725; granulation 2,200.	3	8	Solid band experimental shell; band 3".30 diameter, 0".5 wide; beveled front and rear; old.	13	..	0	....	...	0.00	From rear and right, 67°; 22 miles an hour.
	638	Apr. 2		3	8		13	.	0	.....	..	11.50	
	639	Apr. 2		3	8		13	..	0	.....	...	10.00	
	640	Apr. 2		3	8		13	..	0	....	...	10.00	
	641	Apr. 2		3	8		13	..	0		.	10.00	
	642	Apr. 2		3	8		13	..	0	.....	....	11.25	
	643	Apr. 2		3	8		13	..	0	.....	...	9.67	
	644	Apr. 2		3	8		13	..	0	...	....	10.50	
	645	Apr. 2		3	8		13	..	0	....	....	11.67	
	646	Apr. 2		3	8		13	..	0		....	11.50	
	647	Apr. 2		3	8		13	..	0	....	.....	9.00	
	648	Apr. 2		3	8		13	..	0		....	12.00	
	649	Apr. 2		3	8		13	..	0	.....	....	9.50	
	650	Apr. 2		3	8		13	..	0	....	.	11.67	
	651	Apr. 2		3	8		13	..	0	..	....	9.25	
	652	Apr. 2		3	8		13	..	0	......	.	9.25	
	653	Apr. 2		3	8		13	..	0	....	...	9.25	
	654	Apr. 2		3	8		13	..	0	...	...	11.00	
	655	Apr. 2		3	8		13	..	0	......	.....	10.67	
	656	Apr. 2		3	8		13	..	0	......	....	11.50	
	657	Apr. 2		3	8		13	..	0	......	.....	9.25	
	658	Apr. 2		3	8		13	..	0	....	...	10.33	
	659	Apr. 2		3	8		13	..	0	......	..	9.00	
	660	Apr. 2		3	8		13	..	0	......	....	8.75	
	661	Apr. 2		3	8		13	..	0	......	....	9.50	
	662	Apr. 2		3	8		13	..	0	......	....	9.00	
	663	Apr. 2		3	8		13	..	0	...	.....	8.83	
	664	Apr. 2		3	8		13	..	0	......	....	8.00	
	665	Apr. 2		3	8		13	..	0	...	.....	8.00	
	666	Apr. 2		3	8		13	..	0	......	....	8.00	

Hook, N. J., from October 15, 1884, *to September* 15, 1885—Continued.

Special remarks about each fire, such as effect on piece, sound of projectile in flight, scattering of fragments, &c.
Fired into sand butt. Round 637. Gun mounted on steel field-carriage.
Angle iron, riveted to under side of cheeks of carriage, broken on both sides and cheeks distorted.
Gun mounted on old iron field-carriage.

Record of firing with 3.2-inch breech-loading rifle (steel) at Sandy

	Number of fire.	Time.	Powder. Kind.	Powder. Wgt. Pounds.	Powder. Wgt. Ounces.	Projectile. Kind.	Projectile. Wgt. Pounds.	Projectile. Wgt. Ounces.	Elevation.	Pressure per square inch of bore (crusher).	Instrumental velocity, 100 feet from muzzle.	Recoil.	Wind, strength and direction.
		1885.							° ′	*Lbs.*	*Feet.*	*Feet.*	
A. M.—Barometer, 30.123; thermometer, 33.4; humidity, 71.	667	Apr. 9	Du Pont's I. K. D. Density, 1.725; granulation, 2,200.	3	8	Solid band experimental shell; band 3".30 diameter, 0".5 wide; beveled front and rear.	13	..	0	......	.....	8.75	From rear and right, 42°; 27 miles an hour.
	668	Apr. 9		3	8		13	..	0	......	.....	9.00	
	669	Apr. 9		3	8		13	..	0	......	.....	8.50	
	670	Apr. 9		3	8		13	..	0	......	.....	9.00	
	671	Apr. 9		3	8		13	..	0	....	.....	9.25	
	672	Apr. 9		3	8		13	..	0	......	....	9.42	
	673	Apr. 9		3	8		13	..	0	......	.....	9.16	
	674	Apr. 9		3	8		13	..	0	....	....	9.00	
	675	Apr. 9		3	8		13	..	0	......	....	8.75	
	676	Apr. 9		3	8		13	..	0	......	.....	8.25	
	677	Apr. 9		3	8		13	..	0	......	.....	8.25	
	678	Apr. 9		3	8		13	..	0	....	.....	8.00	
	679	Apr. 9		3	8		13	..	0	......	.....	8.00	
	680	Apr. 9		3	8		13	..	0	......	.....	8.50	
	681	Apr. 9		3	8		13	..	0	......	....	8.25	
	682	Apr. 9		3	8		13	..	0	......	....	8.25	
P. M.—Barometer, 30.123; thermometer, 33.4; humidity, 71.	683	Apr. 9		3	8		13	..	0	......	.....	8.25	From rear and left, 8°; 16 miles an hour.
	684	Apr. 9		3	8		13	..	0	......	....	8.50	
	685	Apr. 9		3	8		13	..	0	......	.....	8.67	
	686	Apr. 9		3	8		13	..	0	......	.....	8.50	
	687	Apr. 9		3	8		13	..	0	......	.....	8.75	
	688	Apr. 9		3	8		13	..	0	......	.....	8.75	
	689	Apr. 9		3	8		13	..	0	......	.....	8.50	
	690	Apr. 9		3	8		13	..	0	......	....	10.00	
	691	Apr. 9		3	8		13	..	0	......	.....	8.67	
	692	Apr. 9		3	8		13	..	0	......	.....	8.67	
	693	Apr. 9		3	8		13	..	0	......	.....	8.75	
	694	Apr. 9		3	8		13	..	0	......	....	8.50	
	695	Apr. 9		3	8		13	..	0	....	.. .	8.50	
	696	Apr. 9		3	8		13	..	0	......	....	8.50	
	697	Apr. 9		3	8		13	..	0	....	.....	8.25	
	698	Apr. 9		3	8		13	..	0	......	..	8.50	
	699	Apr. 9		3	8		13	..	0	......	....	8.67	
	700	Apr. 6		3	8		13	..	0	....	..	8.42	
	701	Apr. 9		3	8		13	..	0	......	....	8.75	

ook, N. J., from October 15, 1884, *to September* 15, 1885—Continued.

Special remarks about each fire, such as effect on piece, sound of p fragments, &c.
Gun star gauged.
Elevating screw replaced by new one.
Elevating screw bent.

Record of firing with 3.2-inch breech-loading rifle (steel) at Sandy

	Number of fire.	Time.	Powder. Kind.	Powder. Wgt. Pounds.	Powder. Wgt. Ounces.	Projectile. Kind.	Projectile. Wgt. Pounds.	Projectile. Wgt. Ounces.	Elevation.	Pressure, per square inch of bore (crusher).	Instrumental velocity, 100 feet from muzzle.	Recoil.	Wind, strength and direction.
		1885.							° ′	*Lbs.*	*Feet.*	*Feet.*	
A. M.—Barometer, 30.115; thermometer 40.8; humidity, 100	702	Apr. 15	Du Pont's L. X. Density, 1.706; granulation, 270.	3	8	Solid-band experimental shell; band 3".3 diameter, 0".5 wide; beveled front and rear.	13	..	0 7	......		7.00	From rear and right, 87°; 16 miles an hour.
	703	Apr. 15		3	8		13	..	0	......	......	7.08	
	704	Apr. 15		3	8		13	..	0	......	......	7.50	
	705	Apr. 15		3	8		13	..	0	......	......	10.00	
	706	Apr. 15		3	8		13	..	0	......	......	11.50	
	707	Apr. 15		3	8		13	..	0	......	......	17.50	
	708	Apr. 15		3	8		13		0	......	......	17.00	
	709	Apr. 15		3	8		13	..	0	......	......	17.00	
P. M.—Barometer, 30.001; thermometer, 41.3; humidity, 89.	710	Apr. 15	Du Pont's I. K. D. Density, 1.725; granulation, 2,200.	3	8	Solid-band experimental shell; band 3".3 diameter, 0".5 wide; beveled front and rear.	13	..	0	......	......	10.50	From rear and left, 49°; 8 miles an hour.
	711	Apr. 15		3	8		13	..	0	......	......	11.75	
	712	Apr. 15		3	8		13		0	......	......	10.50	
	713	Apr. 15		3	8		13	..	0	......	......	10.50	
	714	Apr. 15		3	8		13		0	......	......	11.00	
	715	Apr. 15		3	8		13	..	0	......	......	11.50	
	716	Apr. 15		3	8		13		0	......	......	10.25	
	717	Apr. 15		3	8		13	..	0	......	......	11.50	
	718	Apr. 15		3	8		13	..	0	......	......	11.25	
	719	Apr. 15		3	8		13	..	0	......	......	10.50	
	720	Apr. 15		3	8		13	..	0	......	......	10.50	
	721	Apr. 15		3	8		13	..	0	......	......	10.25	
	722	Apr. 15		3	8		13		0	......	......	10.25	
	723	Apr. 15		3	8		13	..	0	......	......	10.25	
	724	Apr. 15		3	8		13		0	......	......	10.75	
	725	Apr. 15		3	8		13	..	0	......	......	10.00	
	726	Apr. 15		3	8		13	...	0	......	......	10.00	
	727	Apr. 15		3	8		13	..	0	......	......	10.25	
	728	Apr. 15		3	8		13	..	0	......	......	10.25	
	729	Apr. 15		3	8		13	..	0	......	......	10.25	
	730	Apr. 15		3	8		13	.	0	......	......	10.00	
	731	Apr. 15		3	8		13	..	0	......	......	10.25	
	732	Apr. 15		3	8		13	.	0	...	......	10.00	
	733	Apr. 15		3	8		13	...	0	......	......	10.00	

Hook, N. J., from October 15, 1884, *to September* 15, 1885—Continued.

Distance from center of target, in feet.				Distance from center of impact, in feet.				Special remarks about each fire, such as effect on piece, sound of projectile in flight, scattering of fragments, &c.
Vertical.		Horizontal.		Vertical.		Horizontal.		
Above.	Below.	Right.	Left.	Above.	Below.	Right.	Left.	
Fired at target 620 feet from gun.				Sighting shot.				
0.67	....	....	0.42	0.22	....	....	0.06	Target 620 feet from gun. Target 6 x 7 feet. De Bange gas-check. Gun opened and closed easily. No escape of gas.
0.67	....	....	0.12	0.22	....	0.24	....	
0.17	....	....	1.33	....	0.28	....	0.97	
0.58	....	0.36	....	0.13	....	0.72	....	
0.13	....	....	0.08	....	0.52	0.28	....	
0.10	....	....	0.09	....	0.35	0.27	....	
0.83	....	....	0.84	0.28	....	....	0.48	
3.15	....	0.36	2.88	0.95	0.95	1.51	1.51	Mean vertical deviation from center of impact, 0.27 feet. Mean horizontal deviation from center of impact, 0.43 feet. Mean deviation from center of impact, 0.51 feet.
3.15÷7=0.45		2.52÷7=0.36		1.90÷7=0.27		3.02÷7=0.43		
Fired into sand butt.								De Bange gas-check. Gun opened and closed easily. No escape of gas.

Record of firing with 3.2-inch breech-loading rifle (steel) at Sandy

	Number of fire.	Time.	Powder. Kind.	Powder. Wgt. Pounds.	Powder. Wgt. Ounces.	Projectile. Kind.	Projectile. Wgt. Pounds.	Projectile. Wgt. Ounces.	Elevation.	Pressure, per square inch of bore (Crusher).	Instrumental velocity, 100 feet from muzzle.	Recoil.	Wind, strength and direction.
		1885.							° '	*Lbs.*	*Feet.*	*Feet.*	
P. M.—Barometer, 30.001; thermometer, 41.3; humidity, 89.	734	Apr. 15	Dupont's I. K. D. Density, 1.725; granulation, 2.200.	3	8	Solid band experimental shell; band 3".3 diameter, 0".5 wide; beveled front and rear.	13	..	0	.....	.....	10.00	From rear and left, 45°; 8 miles an hour.
	735	Apr. 15		3	8		13	..	0	.....	.....	10.00	
	736	Apr. 15		3	8		13	..	0	.....	.....	10.25	
	737	Apr. 15		3	8		13	..	0	.....	.....	10.00	
	738	Apr. 15		3	8		13	..	0	.....	.....	10.00	
	739	Apr. 15		3	8		13	..	0	.....	.....	10.00	
	740	Apr. 15		3	8		13	..	0	.....	.....	10.25	
	741	Apr. 15		3	8		13	..	0	.....	.....	10.00	
	742	Apr. 15		3	8		13	..	0	.....	.....	10.50	
	743	Apr. 15		3	8		13	..	0	.....	.....	10.25	
	744	Apr. 15		3	8		13	..	0	.....	.....	10.50	
	745	Apr. 15		3	8		13	..	0	.....	.....	10.50	
	746	Apr. 15		3	8		13	..	0	.....	.....	10.25	
	747	Apr. 15		3	8		13		0	.....	.....	10.50	
	748	Apr. 15		3	8		13		0	.....	.....	10.25	
A. M.—Barometer, 29.955; thermometer, 55.4; humidity, 42.	749	Apr. 16	Dupont's L. X. A. Density, 1.706; granulation, 270.	3	8		13	..	2 35	.....	.....	3.50	From rear and left, 30°. 12 miles per hour.
	750	Apr. 16		3	8		13	..	2 35	.....	.....	3.08	10
	751	Apr. 16		3	8		13	..	2 35	.....	.....	3.00	12
	752	Apr. 16		3	8		13	..	2 35	.....	.....	2.75	11
	753	Apr. 16		3	8		13	..	2 35	.....	..	3.75	11
	754	Apr. 16		3	8		13		2 35	.....	.....	3.83	11
P. M.—Barometer, 29.955; thermometer, 55.4; humidity, 42.	755	Apr. 16		3	8		13	..	2 35	.....	.....	3.33	From front and right 45°; 6 miles an hour.
	756	Apr. 16		3	8		13		2 35	.....	..	3.33	From rear and left, 30°; 4 miles an hour.
	757	Apr. 16		3	8		13		2 35	.....	.....	3.00	

., from October 15, 1884, *to September* 15, 1885—Continued.

arks about each fire, such as effect on piece, sound of fragments, &c.

710 to 748 were fired in 50 minutes, gun being sponged out after each 10 rounds.

om center of target, in feet.			Distance from center of impact, in feet.			
.	Horizontal.		Vertical.		Horizontal.	
low.	Right.	Left.	Above.	Below.	Right.	Left.
. 50	2. 66	....	....	0. 81	2. 92	....
. 50	......	2. 50	....	0. 81	....	2. 24
. 00	....	0. 75	....	2. 31	....	0. 49
. 98	0. 33	......	2. 67	......	0. 59	....
. 00	0. 16	....	3. 69	......	0. 42	....
. 00	....	3. 00	....	2. 31	......	2. 74
nder target.						
50	2. 34	....	......	0. 81	2. 60	....
. 00	....	1. 32	0. 69	....	....	1. 06
. 48	5. 49	7. 57	7. 05	7. 05	6. 53	6. 53
. 31	2. 08+8=0. 26		14. 10+8=1. 76		13. 06+8=1. 63	

d a le target; target 20 x 40 feet, made of 1-inch spruce boards.

Gun mounted on 30 pou Parrott carriage.

Record of firing with 3.2-inch breech-loading rifle (steel) at Sandy

	Number of fire.	Time.	Powder.			Projectile.			Elevation.	Pressure per square inch of bore (Crusher).	Instrumental velocity, 100 feet from muzzle.	Recoil.	Wind, strength and direction.
			Kind.	Wgt.		Kind.	Wgt.						
				Pounds.	Ounces.		Pounds.	Ounces.					
		1885.							° '	*Lbs.*	*Feet.*	*Feet.*	
P. M.—Barometer, 30.169; thermometer, 76.2; humidity, 36.	758	Apr. 21	Du Pont's I. K. D. Density, 1.725. Granulation, 2,200.	3	8	Experimental shrapnel, received from Watertown Arsenal April 15, 1885.	13	..	7	....	....	....	From front and left, 7°; 16 miles an hour.
	759	Apr. 21		3	8	Shrapnel, brass head.	12	8	7	....	....	....	
	760	Apr. 21		3	8	Experimental shrapnel, received from Watertown Arsenal April 15, 1885.	13	..	7	....	....	....	
P. M.—Barometer, 30.146; thermometer, 77.3; humidity, 44.	761	Apr. 22		3	8		13		7	....	....	....	From front and right, 45°; 20 miles an hour.
A. M.—Barometer, 30.273; thermometer, 52.1; humidity, 91.	762	Apr. 23		3	8		13	..	0	....	....	....	From front and left, 87°; 10 miles an hour.
	763	Apr. 23		1	8		13		6	....	....	....	From front and left, 12°; 10 miles an hour.
A. M.—Barometer, 30.416; thermometer, 71; humidity, 55.	764	Apr. 24		3	8	Shrapnel, brass head.	12	8	5	....	....	....	From front and right, 45°; 20 miles an hour.
	765	Apr. 24		3	8		12	8	5	....	....	....	
	766	Apr. 24		3	8		12	8	5	....	....	....	
A. M.—Barometer, 29.823; thermometer 47.2; humidity, 68.	767	Apr. 30		3	8	Solid band experimental shell; band 3″.3 diameter, 0″.5 wide; beveled front and rear.	13	.	0	....	....	7.25	From rear and right, 43°; 18 miles an hour.
	768	Apr. 30		3	8		13	..	0	....	....	8.00	
	769	Apr. 30		3	8		13	.	0	....	....	7.75	
	770	Apr. 30		3	8		13	..	0	....	....	7.75	
	771	Apr. 30		3	8		13	..	0	....	....	7.75	
	772	Apr. 30		3	8		13	..	0	....	....	7.75	
	773	Apr. 30		3	8		13	.	0	....	....	8.00	
	774	Apr. 30		3	8		13	..	0	....	....	8.00	
	775	Apr. 30		3	8		13	..	0	....	....	7.67	
	776	Apr. 30		3	8		13	..	0	....	....	7.50	
	777	Apr. 30		3	8		13	..	0	....	....	7.75	
	778	Apr. 30		3	8		13	..	0	....	....	8.00	
	779	Apr. 30		3	8		13	..	0	....	....	7.88	

N. J., from October 15, 1884, *to September* 15, 1885—Continued.

		remarks about each fire, such as effect on piece, sound of projectile in flight, scattering of fragments, &c.
	Metallic time-fuse received from Frankford Arsenal April 21, 1885. Shrapnel used in rounds 758, 760, 761, and 763 contained bursting-charge of 2¼ ounces. Shrapnel used in rounds 759, 764, and 765 contained bursting-charge of 1½ ounces. Shrapnel used in round 762 contained 2½ ounces sand.	Fuse set at 5 seconds. Did not explode. Shell struck water in 10¾ seconds.
		Fuse set at 5 seconds. Broke up.
		Fuse set at 5 seconds. Broke up.
		Fuse set at 5 seconds. Fuse failed to act.
to sand-butt.		Recovered in butt in small fragments. Fuse not exploded.
		Fuse set at 3 seconds. Broke up.
		Fuse set at 3 seconds (wings of plunger cut off). Did not explode.
		Fuse set at 3 seconds (wings of plunger cut off). Burst in $2\frac{7}{10}$ seconds.
		Fuse set at 3 seconds (wings of plunger cut off). Burst in ¾ seconds.
to sand-butt.		De Bange gas check. Breech-block worked admirably.

Record of firing with 3-2-inch breech-loading rifle (steel) at Sandy

	Number of fire.	Time.	Powder. Kind.	Powder. Wgt. Pounds.	Powder. Wgt. Ounces.	Projectile. Kind.	Projectile. Wgt. Pounds.	Projectile. Wgt. Ounces.	Elevation.	Pressure per square inch of bore (Crusher).	Instrumental velocity 100 feet from muzzle.	Recoil	Wind, strength and direction.
		1885.							° ′	Lbs.	Feet.	Feet.	
A. M.—Barometer 29.823; thermometer, 47.2; humidity, 68.	780	Apr. 30	DuPont's I. K. D. Density, 1.725; granulation, 2,200.	3	8	Solid band experimental shell; band 3''.3 diameter, 0''.5 wide; beveled front and rear.	13	..	0	......		8.00	From rear and right 45°; 18 miles an hour.
	781	Apr. 30		3	8		13	..	0	....	.....	7.33	
	782	Apr. 30		3	8		13	..	0	....	...	7.50	
	783	Apr. 30		3	8		13	..	0	......	.. .	7.83	
	784	Apr. 30		3	8		13	..	0	......	....	7.50	
	785	Apr. 30		3	8		13	..	0	....	... .	7.50	
	786	Apr. 30		3	8		13	..	0	......	.....	7.50	
	787	Apr. 30		3	8		13	.	0	......	.....	8.00	
	788	Apr. 30		3	8		13	..	0	......	.....	8.00	
	789	Apr. 30		3	8		13	..	0	......	.....	8.25	
	790	Apr. 30		3	8		13	..	0	......	.....	8.83	
	791	Apr. 30		3	8		13	..	0	......	....	8.83	
	79.	Apr. 30		3	8		13	..	0	......	....	8.50	
	793	Apr. 30		3	8		13	..	0	....	....	8.67	
	794	Apr. 30		3	8		13	..	0	......	....	8.25	
	795	Apr. 30		3	8		13	..	0	......	...	8.33	
	796	Apr. 30		3	8		13	..	0	....	....	7.73	
	797	Apr. 30		3	8		13	..	0	......	....	9.16	
	798	Apr. 30		3	8		13	..	0	......	....	8.33	
	799	Apr. 30		3	8		.3	..	0	......	.....	7.83	
	800	Apr. 30		3	8		13	..	0	......	.....	8.33	
P. M.—Barometer, 30.157; thermometer, 54.1; humidity, 81.	801	May 13	DuPont's I. K. D. Density, 1.725; granulation, 2,200.	3	8	Shrapnel, brass head; plunger from German fuze with wings off.	12	8	7	......	......	.....	From front and left 45°; 20 miles an hour.
	802	May 13		3	8	Solid band experimental shell; band 3''.3 diameter, 0''.5 wide; beveled front and rear.	13	..	38	......	....	.....	
	803	May 13		3	8		13	..	38	......	....	.....	
P. M.—Barometer, 29.966; thermometer, 79.8; humidity, 42.	804	May 26		3	8		13	..	30	......	......	.....	Fr'm rear; 8 miles an hour.

ok, *N. J., from October* 15, 1884, *to September* 15, 1885—Continued.

pecial remarks about each fire, such as effect on piece, sound of projectile in flight, scattering of fragments, &c.
er round 786 the gun was sponged out, and bent elevating screws replaced by new ones.
ed into sand butt. De Bange gas-check. Breech-block worked admirably. Time of firing rounds 7-800, including interval, 50 minutes.
ashed out, star-gauged, and impressions taken of vent. Mounted on 30-pounder
ired over water; struck in 10 seconds. Metallic time-fuze received from 21, 1885; did not explode.
red over water for range. Lost.
Do.
Do.

Record of firing with 3.2-inch breech-loading rifle (steel) at Sandy

	Number of fire.	Time.	Powder. Kind.	Powder. Wgt. Pounds.	Powder. Wgt. Ounces.	Projectile. Kind.	Projectile. Wgt. Pounds.	Projectile. Wgt. Ounces.	Elevation.	Pressure, per square inch of bore (Crusher).	Instrumental velocity, 100 feet from muzzle.	Recoil.	Wind, strength and direction.
		1885.							° ′	*Lbs.*	*Feet.*	*Feet.*	
P. M.—Barometer, 29.890; thermometer, 70.8; humidity, 46.	805	June 2	Du Pont's I. K. D. Density, 1.725; granulation, 2,200.	3	8	Solid band experimental shell; band 3″.3 diameter, 0″.5 wide; beveled front and rear.	13	..	0	......	.....	.....	From rear and right, 43°, 26 miles an hour.
	806	June 2		3	8		13	..	0	......	.....	.....	
	807	June 2		3	8		13	..	0	......	.....	.....	
	808	June 2		3	8		13	..	0	......	.....	.....	
	809	June 2		3	8		13	..	0	......	.....	.....	
	810	June 2		3	8		13	..	0	28,150	.....	.....	
	811	June 2		3	8		13	..	0	......	.....	.....	
	812	June 2		3	8		13	..	0	......	.....	.....	
	813	June 2		3	8		13	..	0	......	.....	.....	
	814	June 2		3	8		13	..	0	......	.....	.....	
	815	June 2		3	8		13	..	0	......	.....	.....	
	816	June 2		3	8		13	..	0	......	.....	.....	
	817	June 2		3	8		13	..	0	......	.....	.....	
	818	June 2		3	8		13	..	0	......	.....	.....	
	819	June 2		3	8		13	..	0	......	.....	.....	
	820	June 2		3	8		13	..	0	......	.....	.....	
	821	June 2		3	8		13	..	0	......	.....	.....	
	822	June 2		3	8		13	..	0	......	.....	.....	
	823	June 2		3	8		13	..	0	......	.....	.....	
	824	June 2		3	8		13	..	0	......	.....	.....	
	825	June 2		3	8		13	..	0	......	.....	.....	
	826	June 2		3	8		13	..	0	......	.....	.....	
	827	June 2		3	8		13	..	0	......	.....	.....	
	828	June 2		3	8		13	..	0	......	.....	.....	
	829	June 2		3	8		13	..	0	......	.....	.....	
	830	June 2		3	8		13	..	0	......	.....	.....	
	831	June 2		3	8		13	..	0	......	.....	.....	
	832	June 2		3	8		13	..	0	......	.....	.....	
	833	June 2		3	8		13	..	0	......	.....	.....	
	834	June 2		3	8		13	..	0	......	.....	.....	
	835	June 2		3	8		13	..	0	......	.....	.....	
	836	June 2		3	8		13	..	0	......	.....	.....	
	837	June 2		3	8		13	..	0	......	.....	.....	

ok, *N. J., from October* 15, 1884, *to September* 15, 1885—Continued.

ecial remarks about each fire, such as effect on piece, sound of projectile in flight, scattering of fragments, &c.	
Gun mounted on old field carriage.	
Raw-silk cartridge-bag.	After this round there was quite a large fragment of unconsumed bag in chamber.
	Vent was not pricked and cartridge failed to ignite. Bag unconsumed.
	The mushroom head was coated with remnants of bag mixed with usual powder residue.

minutes.

un cleaned out.

Record of firing with 3.2-inch breech-loading rifle (steel) at Sandy

	Number of fire.	Time.	Powder. Kind.	Powder. Wgt. Pounds.	Powder. Wgt. Ounces.	Projectile. Kind.	Projectile. Wgt. Pounds.	Projectile. Wgt. Ounces.	Elevation.	Pressure per square inch of bore (Crusher).	Instrumental velocity, 100 feet from muzzle.	Recoil.	Wind, strength and direction.
		1885.							° ′	*Lbs.*	*Feet.*	*Feet.*	
P. M.—Barometer, 29.890; thermometer, 70.8; humidity, 46.	838	June 2	Du Pont's I. K. D. Density, 1.725; granulation, 2.200.	3	8	Solid band experimental shell; band 3″.3 diameter, 0″.5 wide; beveled front and rear.	13		0				From rear and right, 43°; 20 miles an hour.
	839	June 2		3	8		13		0				
	840	June 2		3	8		13		0				
	841	June 2		3	8		13		0				
	842	June 2		3	8		13		0				
	843	June 2		3	8		13		0				
	844	June 2		3	8		13		0				
	845	June 2		3	8		13		0				
	846	June 2		3	8		13		0				
	847	June 2		3	8		13		0				
	848	June 2		3	8		13		0				
	849	June 2		3	8		13		0				
	850	June 2		3	8		13		0				
	851	June 2		3	8		13		0				
	852	June 2		3	8		13		0				
	853	June 2		3	8		13		0				
	854	June 2		3	8		13		0				
P. M.—Barometer, 30.061; thermometer, 65.8; humidity, 42.	855	June 9		3	8		13		0				From rear and right, 43°; 21 miles an hour.
	856	June 9		3	8		13		0				
	857	June 9		3	8		13		0				
	858	June 9		3	8		13		0				
	859	June 9		3	8		13		0				
	860	June 9		3	8		13		0				
	861	June 9		3	8		13		0				
	862	June 9		3	8		13		0				
	863	June 9		3	8		13		0				
	864	June 9		3	8		13		0				
	865	June 9		3	8		13		0				
	866	June 9		3	8		13		0				
	867	June 9		3	8		13		0				
	868	June 9		3	8		13		0				

Hook, N. J., from October 15, 1884, *to September* 15, 1885—**Continued.**

Special remarks about each fire, such as effect on piece, sound of projectile in flight, scattering of fragments, &c.
Fired into sand butt. De Bangé gas-check.
Fired in 18 minutes.
Gun star gauged and impression of vent taken
1 bolt on carriage taken.
Fired in 23 minutes.

Record of firing with 3.2-inch breech-loading rifle (steel) at Sandy

	Number of fire.	Time.	Powder.			Projectile.			Elevation.	Pressure, per square inch of bore (Crusher).	Instrumental velocity 100 feet from muzzle.	Recoil.	Wind, strength and direction.
			Kind.	Wgt Pounds.	Wgt Ounces.	Kind.	Wgt Pounds.	Wgt Ounces.					
		1885.							° '	*Lbs.*	*Feet.*	*Feet.*	
P. M.—Barometer, 30.001; thermometer, 65.8; humidity, 42.	869	June 9	DuPont's I. K. D. Density, 1.725; granulation, 2,200.	3	8	Solid-band experimental shell; band 3".3 diameter, 0".5 wide; beveled front and rear.	13	..	0	......	......	......	From rear and right, 43°; 21 miles an hour.
	870	June 9		3	8		13	..	0	......	......	......	
	871	June 9		3	8		13	..	0	......	......	......	
	872	June 9		3	8		13	..	0	......	......	......	
	873	June 9		3	8		13	..	0	......	......	......	
	874	June 9		3	8		13	..	0	......	......	......	
	875	June 9		3	8		13	..	0	......	......	......	
	876	June 9		3	8		13	..	0	......	......	......	
	877	June 9		3	8		13	..	0	......	......	......	
	878	June 9		3	8		13	..	0	......	......	......	
	879	June 9		3	8		13	..	0	......	......	......	
	880	June 9		3	8		13	..	0	......	......	......	
	881	June 9		3	8		13	..	0	......	......	......	
	882	June 9		3	8		13	..	0	......	......	......	
	883	June 9		3	8		13	..	0	......	......	......	
	884	June 9		3	8		13	..	0	......	......	......	
	885	June 9		3	8		13	..	0	......	......	......	
	886	June 9		3	8		13	..	0	......	......	......	
	887	June 9		3	8		13	..	0	......	......	......	
	888	June 9		3	8		13	..	0	......	......	......	
	889	June 9		3	8		13	..	0	......	......	......	
	890	June 9		3	8		13	..	0	......	......	......	
	891	June 9		3	8		13	..	0	......	......	......	
	892	June 9		3	8		13	..	0	......	......	......	
	893	June 9		3	8		13	..	0	......	......	......	
	894	June 9		3	8		13	..	0	......	......	......	
	895	June 9		3	8		13	..	0	......	......	......	
	896	June 9		3	8		13	..	0	......	......	......	
	897	June 9		3	8		13	..	0	......	......	......	
	898	June 9		3	8		13	..	0	......	......	......	
	899	June 9		3	8		13	..	0	......	......	......	

Hook, N. J., from October 15, 1884, *to September* 15, 1885—Continued.

Special remarks about each fire, such as effect on piece, sound fragments, &c.
Fired into sand butt. De Range gas-check.
Rounds 855–879 fired in 23 minutes.
Gun washed out.
Rounds 880–904 fired in 23 minutes.

Record of firing with 3.2-*inch breech-loading rifle* (*steel*) *at Sandy*

	Number of fire.	Time.	Powder.			Projectile.			Elevation.	Pressure per square inch of bore (Crusher).	Instrumental velocity 100 feet from muzzle.	Recoil.	Wind, strength and direction.
			Kind.	Wgt. Pounds.	Wgt. Ounces.	Kind.	Wgt. Pounds.	Wgt. Ounces.					
		1883.							° '	*Lbs.*	*Feet.*	*Feet.*	
P. M.—Barometer, 30.001; thermometer, 65.8; humidity, 42.	900	June 9	Du Pont's I. K. D. Density, 1.725; granulation, 2.200.	3	8	Solid band experimental shell; band 3".3 diameter, 0".5 wide; beveled front and rear.	13	..	0	......	......	......	From rear and right, 42°; 21 miles an hour.
	901	June 9		3	8		13	..	0	......	......	......	
	902	June 9		3	8		13	..	0	......	......	......	
	903	June 9		3	8		13	..	0	......	......	......	
	904	June 9		3	8		13	..	0	......	......	......	
	905	June 9		3	8		13	..	0	......	......	......	
	906	June 9		3	8		13	..	0	......	......	......	
	907	June 9		3	8		13	..	0	......	......	......	
	908	June 9		3	8		13	..	0	......	......	......	
	909	June 9		3	8		13	..	0	......	......	......	
	910	June 9		3	8		13	..	0	......	......	......	
	911	June 9		3	8		13	..	0	......	......	......	
	912	June 9		3	8		13	..	0	......	......	......	
	913	June 9		3	8		13	..	0	......	......	......	
	914	June 9		3	8		13	..	0	......	......	......	
	915	June 9		3	8		13	..	0	......	......	......	
	916	June 9		3	8		13	..	0	......	......	......	
	917	June 9		3	8		13	..	0	......	......	......	
	918	June 9		3	8		13	..	0	......	......	......	
	919	June 9		3	8		13	..	0	......	......	......	
	920	June 9		3	8		13	..	0	......	......	......	
	921	June 9		3	8		13	..	0	......	......	......	
	922	June 9		3	8		13	..	0	......	......	......	
	923	June 9		3	8		13	..	0	......	......	......	
	924	June 9		3	8		13	..	0	......	......	......	
	925	June 9		3	8		13	..	0	......	......	......	
	926	June 9		3	8		13	..	0	......	......	......	
	927	June 9		3	8		13	..	0	......	......	......	
	928	June 9		3	8		13	..	0	......	......	......	
	929	June 9		3	8		13	..	0	......	......	......	
	930	June 9		3	8		13	..	0	......	......	......	

Hook, N. J., from October 15, 1884, *to September* 15, 1885—Continued.

Special remarks about each fire, such as effect on piece, sound of projectile in flight, scattering of fragments, &c.
Fired into sand butt. De Bange gas-check.
Rounds 880-904 fired in 23 minutes.
Gun washed out.
Trail handspike broke.

Record of firing with 3.2-inch breech-loading rifle (steel) at Sandy

	Number of fire.	Time.	Powder.			Projectile.			Elevation.	Pressure per square inch of bore (Crusher).	Instrumental velocity 100 feet from muzzle.	Recoil.	Wind, strength and direction.
			Kind.	Wgt. Pounds.	Wgt. Ounces.	Kind.	Wgt. Pounds.	Wgt. Ounces.					
		1885.							° ′	Lbs.	Feet.	Feet.	
P. M.—Barometer, 30.001; thermometer, 65.8; humidity, 42.	931	June 9	DuPont's I. K. D. Density, 1.725; granulation, 2,200.	3	8	Solid band experimental shell; band 3″.3 in diameter, 0″.5 wide; beveled front and rear.	13	..	0	......	......	......	From rear and right 43°, 21 miles an hour.
	932	June 9		3	8		13	..	0	......	......	......	
	933	June 9		3	8		13	..	0	......	......	......	
	934	June 9		3	8		13	..	0	......	......	......	
	935	June 9		3	8		13	..	0	......	......	......	
	936	June 9		3	8		13	..	0	......	......	......	
	937	June 9		3	8		13	..	0	......	......	......	
	938	June 9		3	8		13	..	0	......	......	......	
	939	June 9		3	8		13	..	0	......	......	......	
	940	June 9		3	8		13	..	0	......	......	......	
	941	June 9		3	8		13	..	0	......	......	......	
	942	June 9		3	8		13	..	0	......	......	......	
	943	June 9		3	8		13	..	0	......	......	......	
	944	June 9		3	8		13	..	0	......	......	......	
	945	June 9		3	8		13	..	0	......	......	......	
	946	June 9		3	8		13	..	0	......	......	......	
	947	June 0		3	8		13	..	0	......	......	......	
	948	June 9		3	8		13	..	0	......	......	......	
	949	June 9		3	9		13	..	0	......	......	......	
	950	June 9		3	8		13	..	0	......	......	......	
	951	June 9		3	8		13	..	0	......	......	......	
	952	June 9		3	8		13	..	0	......	......	......	
	953	June 9		3	8		13	..	0	......	......	......	
	954	June 9		3	8		13	..	0	......	......	......	
A. M.—Barometer, 30.097; thermometer, 65.9; humidity, 46.	955	June 10		3	8		13	..	0	......	......	......	From rear and right 43°, 8 miles an hour.
	956	June 10		3	8		13	..	0	......	......	......	
	957	June 10		3	8		13	..	0	......	......	......	
	958	June 10		3	8		13	..	0	......	......	......	
	959	June 10		3	8		13	..	0	......	......	......	
	960	June 10		3	8		13	..	0	......	......	......	
	961	June 10		3	8		13	..	0	......	......	......	

Hook, N. J., from October 15, 1881, *to September* 15, 1885—Continued.

pecial remarks about each fire, such as effect on piece, sound of projectile in flight, scattering of fragments, &c.
Fired into sand butt. De Bange gas check. Rounds 905-954, inclusive, fired in 40 minutes.
Gun star gauged and impressions taken of vent. New copper vent bushing put in.

Record of firing with 3.2-inch breech-loading rifle (steel) at Sandy

	Number of fire.	Time.	Powder. Kind.	Powder. Wgt. Pounds.	Powder. Wgt. Ounces.	Projectile. Kind.	Projectile. Wgt. Pounds.	Projectile. Wgt. Ounces.	Elevation.	Pressure per square inch of bore (Crusher).	Instrumental velocity 100 feet from muzzle.	Recoil.	Wind, strength and direction.
		1885.							° ′	*Lbs.*	*Feet.*	*Feet.*	
A. M.—Barometer 30.097; thermometer, 65.9; humidity, 46.	962	June 10	DuPont's I. K. D. Density, 1.725. Granulation, 2200.	3	8	Solid-band experimental shell. Band, 3″.3 diameter, 0″.5 wide; beveled front and rear.	13	..	0	......	......	......	From rear and right, 45°; 8 miles an hour.
	963	June 10		3	8		13	..	0	......	......	......	
	964	June 10		3	8		13	..	0	......	......	......	
	965	June 10		3	8		13	..	0	......	......	......	
	966	June 10		3	8		13	..	0	......	......	......	
	967	June 10		3	8		13	..	0	......	......	......	
	968	June 10		3	8		13	..	0	......	......	......	
	969	June 10		3	8		13	..	0	......	......	......	
	970	June 10		3	8		13	..	0	......	......	......	
	971	June 10		3	8		13	..	0	......	......	......	
	972	June 10		3	8		13	..	0	......	......	......	
	973	June 10		3	8		13	..	0	......	......	......	
	974	June 10		3	8		13	..	0	......	......	......	
	975	June 10		3	8		13	..	0	......	......	......	
	976	June 10		3	8		13	..	0	......	......	......	
	977	June 10		3	8		13	..	0	......	......	......	
	978	June 10		3	8		13	..	0	......	......	......	
	979	June 10		3	8		13	..	0	......	......	......	
	980	June 10		3	8		13	..	0	......	......	......	
	981	June 10		3	8		13	..	0	......	......	......	
	982	June 10		3	8		13	..	0	......	......	......	
	983	June 10		3	8		13	..	0	......	......	......	
	984	June 10		3	8		13	..	0	......	......	......	
	985	June 10		3	8		13	..	0	......	......	......	
	986	June 10		3	8		13	..	0	......	......	......	
	987	June 10		3	8		13	..	0	......	......	......	
	988	June 10		3	8		13	..	0	......	......	......	
	989	June 10		3	8		13	..	0	......	......	......	
	990	June 10		3	8		13	..	0	......	......	......	
	991	June 10		3	8		13	..	0	......	......	......	
	992	June 10		3	8		13	..	0	......	......	......	

N. J., from October 15, 1884, *to September* 15, 1885—Continued.

l remarks about each fire, such as effect on piece, sound of projectile in flight, scattering of fragments, &c.
into sand butt. De Bange gas-check.

Record of firing with 3.2 inch breech-loading rifle (steel) at Sandy

	Number of fire.	Time.	Powder. Kind.	Powder. Wgt Pounds.	Powder. Wgt Ounces.	Projectile. Kind.	Projectile. Wgt Pounds.	Projectile. Wgt Ounces.	Elevation.	Pressure, per square inch of bore (Crusher).	Instrumental velocity 100 feet from muzzle.	Recoil.	Wind, strength and direction.
		1885.							° '	Lbs.	Feet.	Feet.	
A. M.—Barometer, 30.097; thermometer, 65.9; humidity, 46	993	June 10	DuPont's I. K. D. Density, 1.725; granulation, 1200.	3	8	Solid band experimental shell; band 3".3 diameter, 0".5 wide; beveled front and rear.	13	..	0	......	......	......	From rear and right, 43°; 8 miles an hour.
	994	June 10		3	8		13	..	0	......	......	......	
	995	June 10		3	8		13	..	0	......	......	......	
	996	June 10		3	8		13	..	0	......	......	......	
	997	June 10		3	8		13	..	0	......	......	......	
	998	June 10		3	8		13	..	0	......	......	......	
	999	June 10		3	8		13	..	0	......	......	......	
	1000	June 10		3	8		13	..	0	......	......	......	
	1001	June 10		3	8		13	..	0	......	......	......	
	1002	June 10		3	8		13	..	0	......	......	......	
	1003	June 10		3	8		13	..	0	......	......	......	
	1004	June 10		3	8		13	..	0	......	......	......	
	1005	June 10		3	8		13	..	0	......	......	......	
	1006	June 10		3	8		13	..	0	......	......	......	
	1007	June 10		3	8		13	..	0	......	......	......	
	1008	June 10		3	8		13	..	0	......	......	......	
	1009	June 10		3	8		13	..	0	......	......	......	
	1010	June 10		3	8		13	..	0	......	......	......	
	1011	June 10		3	8		13	..	0	......	......	......	
	1012	June 10		3	8		13	..	0	......	......	......	
	1013	June 10		3	8		13	..	0	......	......	......	
	1014	June 10		3	8		13	..	0	......	......	......	
	1015	June 10		3	8		13	..	0	......	......	......	
	1016	June 10		3	8		13	..	0	......	......	......	
	1017	June 10		3	8		13	..	0	......	......	......	
	1018	June 10		3	8		13	..	0	......	......	......	
	1019	June 10		3	8		13	..	0	......	......	......	
	1020	June 10		3	8		13	..	0	......	......	......	
	1021	June 10		3	8		13	..	0	......	......	......	
	1022	June 10		3	8		13	..	0	......	......	......	
	1023	June 10		3	8		13	..	0	......	......	......	
	1024	June 10		3	8		13	..	0	......	......	......	
	1025	June 10		3	8		13	..	0	......	......	......	
	1026	June 10		3	8		13	..	0	......	......	......	
	1027	June 10		3	8		13	..	0	......	......	......	
	1028	June 10		3	8		13	..	0	......	......	......	

N. J., from October 15, 1881, *to September* 15, 1885—Continued.

l remarks about each fire, such as effect on piece, sound of projectile in flight, scattering of fragments, &c.
ounds 955–1054. After these 100 rounds, temperature of chase ime of firing, 1 hour and 30 minutes.

Record of firing with 3.2-inch breech-loading rifle (steel) at Sandy

	Number of fire.	Time.	Powder. Kind.	Powder. Wgt. Pounds.	Powder. Wgt. Ounces.	Projectile. Kind.	Projectile. Wgt. Pounds.	Projectile. Wgt. Ounces.	Elevation.	Pressure, per square inch of bore (Crusher).	Instrumental velocity 100 feet from muzzle.	Recoil.	Wind, strength and direction.
		1885							° ′	Lbs.	Feet.	Feet.	
A. M.—Barometer, 30.297; thermometer, 65.9; humidity, 46.	1029	June 10	Du Pont's I. K. D. Density, 1.725; granulation, 2.200.	3	8	Solid band experimental shell; band 3″.3 diameter, 0″.5 wide; beveled front and rear.	13		0	....	....	....	From rear and right 45°, 8 miles an hour.
	1030	June 10		3	8		13		0	....	....	....	
	1031	June 10		3	8		13		0	....	....	....	
	1032	June 10		3	8		13		0	....	....	....	
	1033	June 10		3	8		13		0	....	....	....	
	1034	June 10		3	8		13		0	....	....	....	
	1035	June 10		3	8		13		0	....	....	....	
	1036	June 10		3	8		13		0	....	....	....	
	1037	June 10		3	8		13		0	....	....	....	
	1038	June 10		3	8		13		0	....	....	....	
	1039	June 10		3	8		13		0	....	....	....	
	1040	June 10		3	8		13		0	....	....	....	
P. M.—Barometer, 30.097; thermometer, 65.9; humidity, 46.	1041	June 10		3	8		13		0	....	....	....	
	1042	June 10		3	8		13		0	....	....	....	
	1043	June 10		3	8		13		0	....	....	....	
	1044	June 10		3	7		13		0	....	....	....	
	1045	June 10		3	8		13		0	....	....	....	
	1046	June 10		3	8		13		0	....	....	....	
	1047	June 10		3	8		13		0	....	....	....	
	1048	June 10		3	8		13		0	....	....	....	
	1049	June 10		3	8		13		0	....	....	....	
	1050	June 10		3	8		13		0	....	....	....	
	1051	June 10		3	8		13		0	....	....	....	
	1052	June 10		3	8		13		0	....	....	....	
	1053	June 10		3	8		13		0	....	....	....	
	1054	June 10		3	8		13		0	....	....	....	
P. M.—Barometer, 30.200; thermometer, 63.3; humidity, 49.	1055	June 10		3	8		13		0	....	....	....	From front and right 9°, 24 miles an hour.
	1056	June 10		3	8		13		0	....	....	....	
	1057	June 10		3	8		13		0	....	....	....	
	1058	June 10		3	8		13		0	....	....	....	
	1059	June 10		3	8		13		0	....	....	....	
	1060	June 10		3	8		13		0	....	....	....	
	1061	June 10		3	8		13		0	....	....	....	
	1062	June 10		3	8		13		0	....	....	....	
	1063	June 10		3	8		13		0	....	....	....	
	1064	June 10		3	8		13		0	....	....	....	

Hook, N. J., from October 15, 1884, *to September* 15, 1885—Continued.

	Special remarks about each fire, such as effect on piece, sound of projectile in flight, scattering of fragments, &c.
Fired into sand butt. De Bange gas-check.	Rounds 955 to 1,054. After these 100 rounds temperature of chase near muzzle, 374° Fahrenheit Time of firing, 1 hour and 30 minutes. Gun star-gauged while hot immediately after firing; gun star-gauged when cool.
	Rounds 1,055 to 1,100, inclusive, fired in 23 minutes.

Record of firing with 3.2-*inch breech-loading rifle* (*steel*) *at Sand*

	Number of fire.	Time.	Powder.			Projectile.			Elevation.	Pressure, per square inch of bore (Crusher).	Instrumental velocity, 100 feet from muzzle.	Recoil.	Wind, strength and direction.
			Kind.	Wgt. Pounds.	Wgt. Ounces.	Kind.	Wgt. Pounds.	Wgt. Ounces.					
		1885.							° ′	*Lbs.*	*Feet.*	*Feet.*	
P. M.—Barometer, 30.260; thermometer, 69.3; humidity, 49.	1065	June 10	Du Pont's I. K. D. Density, 1.725; granulation, 2.200.	3	8	Solid-band experimental shell; band 3″.3 diameter, 0″.5 wide; beveled front and rear.	13	..	0				From front and right 30°, 24 miles an hour.
	1066	June 10		3	8		13	..	0				
	1067	June 10		3	8		13	..	0				
	1068	June 10		3	8		13	..	0				
	1069	June 10		3	8		13	..	0				
	1070	June 10		3	8		13	..	0				
	1071	June 10		3	8		13	..	0				
	1072	June 10		3	8		13	..	0				
	1073	June 10		3	8		13	..	0				
	1074	June 10		3	8		13	..	0				
	1075	June 10		3	8		13	..	0				
	1076	June 10		3	8		13	..	0				
	1077	June 10		3	8		13	..	0				
	1078	June 10		3	8		13	..	0				
	1079	June 10		3	8		13	..	0				
	1080	June 10		3	8		13	..	0				
	1081	June 10		3	8		13	..	0				
	1082	June 10		3	8		13	..	0				
	1083	June 10		3	8		13	..	0				
	1084	June 10		3	8		13	..	0				
	1085	June 10		3	8		13	..	0				
	1086	June 10		3	8		13	..	0				
	1087	June 10		3	8		13	..	0				
	1088	June 10		3	8		13	..	0				
	1089	June 10		3	8		13	..	0				
	1090	June 10		3	8		13	..	0				
	1091	June 10		3	8		13	..	0				
	1092	June 10		3	8		13	..	0				
	1093	June 10		3	8		13	..	0				
	1094	June 10		3	8		13	..	0				
	1095	June 10		3	8		13	..	0				
	1096	June 10		3	8		13	..	0				
	1097	June 10		3	8		13	..	0				
	1098	June 10		3	8		13	..	0				
	1099	June 10		3	8		13	..	0				
	1100	June 10		3	8		13	..	0				

Hook, N. J., from October 15, 1884, *to September* 15, 1885—Continued.

Special remarks about each fire, such as effect on piece, sound of projectile in flight, scattering of fragments, &c.
Fired into sand butt. De Bange gas-check. Rounds 1,055 to 1,100, inclusive, fired in 23 minutes.

Record of firing with 3.2-*inch breech-loading rifle* (*steel*) *at*

	Number of fire.	Time.	Powder. Kind.	Powder. Wgt. Pounds.	Powder. Wgt. Ounces.	Projectile. Kind.	Projectile. Wgt. Pounds.	Projectile. Wgt. Ounces.	Elevation.	Pressure per square inch of bore (Crusher).	Instrumental velocity 100 feet from muzzle.	Recoil.	Wind strength and di
		1885.							° ′	*Lbs.*	*Feet.*	*Feet.*	
P. M.—Barometer, 29.994; thermometer, 87.9; humidity, 51.	1101	June 16	Du Pont's I. K. D. Density, 1.725; granulation, 2,200.	3	8	Solid-band experimental shell; band 3″.3 diameter, 0″.5 wide; beveled front and rear.	13	..	0	32,075	1,642	.....	From front: 14 miles an hour
	1102	June 16		3	8		13	..	0	31,900	1,633	.....	
	1103	June 16		3	8		13	..	0	32,025	1,616	.....	
	1104	June 16		3	8		13	..	0	.....	.....	.....	
	1105	June 16		3	8		13	..	0	.....	.....	.....	
	1106	June 16		3	8		13	..	0	.....	.....	.....	
	1107	June 16		3	8		13	..	0	.....	.....	.....	
	1108	June 16		3	8		13	..	0	.....	.....	.....	
	1109	June 16		3	8		13	..	0	.....	.....	.....	
	1110	June 16		3	8		13	..	0	.....	.....	.....	
	1111	June 16		3	8		13	..	0	.....	.....	.....	
	1112	June 16		3	8		13	..	0	.....	.....	.....	
	1113	June 16		3	8		13	..	0	.....	.....	.....	
	1114	June 16		3	8		13	..	0	.....	.....	.....	
	1115	June 16		3	8		19	..	0	.....	.....	.....	
	1116	June 16		3	8		13	..	0	.....	.....	.....	
	1117	June 16		3	8		13	..	0	.....	.....	.....	
	1118	June 16		3	8		13	..	0	.....	.....	.....	
	1119	June 16		3	8		13	..	0	.....	.....	.....	
	1120	June 16		3	8		13	..	0	.....	.....	.....	
	1121	June 16		3	8		13	..	0	.....	.....	.....	
	1122	June 16		3	8		13	..	0	.....	.....	.....	
	1123	June 16		3	8		13	..	0	.....	.....	.....	
	1124	June 16		3	8		13	..	0	.....	.....	.....	
	1125	June 16		3	8		13	..	0	.....	.....	.....	
	1126	June 16		3	8		13	..	0	.....	.....	.....	
	1127	June 16		3	8		13	..	0	.....	.....	.....	
	1128	June 16		3	8		13	..	0	.....	.....	.....	
	1129	June 16		3	8		13	..	0	.....	.....	.....	
	1130	June 16		3	8		13	..	0	.....	.....	.....	
	1131	June 16		3	8		13	..	0	.....	.....	.....	
	1132	June 16		3	8		13	..	0	.....	.....	.....	
	1133	June 16		3	8		13	..	0	.....	.....	.....	
	1134	June 16		3	8		13	..	0	.....	.....	.....	
	1135	June 16		3	8		13	..	0	.....	.....	.....	
	1136	June 16		3	8		13	..	0	.....	.....	.....	

k, N. J., *from October* 15, 1884, *to September* 15, 1885—Continued.

	ial remarks about each fire, such as effect on piece, sound of projectile in flight, scattering of fragments, &c.
Rounds 1209 to 1250 fired in 35 minutes.	Gun wiped out with oil sponge, and formeture cleaned off with waste.

Record of firing with 3.2-*inch breech-loading rifle* (*steel*) *at Sandy*

	Number of fire.	Time.	Powder.			Projectile.			Elevation.	Pressure per square inch of bore (Crusher).	Instrumental velocity 100 feet from muzzle.	Recoil.	Wind, strength and direction.
			Kind.	Wgt. Pounds.	Wgt. Ounces.	Kind.	Wgt. Pounds.	Wgt. Ounces.					
		1885.							° '	*Lbs.*	*Feet.*	*Feet.*	
P. M.—Barometer, 29.904; thermometer, 87.9; humidity, 51.	1137	June 16	Du Pont's I. K. D. Density, 1.725; granulation, 2,200.	3	8	Solid-band experimental shell; band 3".3 diameter, 0".5 wide; beveled front and rear.	13		0				From front; 14 miles an hour.
	1138	June 16		3	8		13		0				
	1139	June 16		3	8		13		0				
	1140	June 16		3	8		13		0				
	1141	June 16		3	8		13		0				
	1142	June 16		3	8		13		0				
	1143	June 16		3	8		13		0				
	1144	June 16		3	8		13		0				
	1145	June 16		3	8		13		0				
	1146	June 16		3	8		13		0				
	1147	June 16		3	8		13		0				
	1148	June 16		3	8		13		0				
	1149	June 16		3	8		13		0				
	1150	June 16		3	8		13		0				
	1151	June 16		3	8		13		0				
	1152	June 16		3	8		13		0				
	1153	June 16		3	8		13		0				
	1154	June 16		3	8		13		0				
	1155	June 16		3	8		13		0				
	1156	June 16		3	8		13		0				
	1157	June 16		3	8		13		0				
	1158	June 16		3	8		13		0				
	1159	June 16		3	8		13		0				
	1160	June 16		3	8		13		0				
	1161	June 16		3	8		13		0				
	1162	June 16		3	8		13		0				
	1163	June 16		3	8		13		0				
	1164	June 16		3	8		13		0				
	1165	June 16		3	8		13		0				
	1166	June 16		3	8		13		0				
	1167	June 16		3	8		13		0				
A. M.—Barometer, 29.903; thermometer, 63.1; humidity, 77.	1168	June 17		3	8	Experimental shrapnel, received from Watertown Arsenal April 15, 1885.	13		0				From front; 6 miles an hour.

ook, N. J., from October 15, 1884, *to September* 15, 1885—Continued.

	Special remarks about each fire, such as effect on piece, sound of projectile in flight, scattering of fragments, &c.
	Rounds 1104-1167 fired in one hour.
	Gun star-gauged.
To try metallic time-fuzes received from Frankford Arsenal June 15, 1885.	Fuze marked A1. Fulminate removed. No bursting charge. Shrapnel broke up in butt; fuze recovered intact.

Record of firing with 3.2-inch breech-loading rifle (steel) at Sandy

	Number of fire.	Time.	Powder. Kind.	Powder. Wgt. Pounds.	Powder. Wgt. Ounces.	Projectile. Kind.	Projectile. Wgt. Pounds.	Projectile. Wgt. Ounces.	Elevation.	Pressure per square inch of bore (Crusher).	Instrumental velocity 100 feet from muzzle.	Recoil.	Wind, strength and direction.
		1885.							° ′	*Lbs.*	*Feet.*	*Feet.*	
A. M.—Barometer, 29.903; thermometer, 63.1; humidity, 77.	1169	June 17	DuPont's I. K. D. Density, 1.725; granulation, 2,200.	3	8	Shrapnel; brass head.	12	12	5	......	......	......	From front and right, 87°; 6 miles an hour.
	1170	June 17		3	8		12	8	5	......	......	......	
	1171	June 17		3	8		12	12	5	......	......	......	
	1172	June 17		3	8		12	12	0	......	......	......	From front, 6 miles an hour.
A. M.—Barometer, 30.222; thermometer, 66.3; humidity, 58.	1173	June 18		3	8	Solid band experimental shell; band 3″.3 diameter, 0″.5 wide; beveled front and rear.	13	..	5	......	......	......	From rear and right, 43°; 8 miles an hour.
	1174	June 18		3	8		13	..	5	......	......	......	
	1175	June 18		3	8		13	..	5	......	......	......	
P. M.—Barometer, 30.194; thermometer, 77.3; humidity, 50.	1176	June 19		3	8		13	..	5	......	......	......	From front and right, 45°; 14 miles an hour.
A. M.—Barometer, 30.224; thermometer, 72.8; humidity, 52.	1177	June 24	DuPont's I. K. B. Density, 1.725; granulation, 2,200.	3	8		13	..	0	30,975	1,651	......	From rear and right, 43°; 12 miles an hour.
	1178	June 24		3	8		13	..	0	31,000	1,641	......	
	1179	June 24		3	8		13	..	0	29,800	1,643	......	
A. M.—Barometer, 29.949; thermometer, 73.8; humidity, 69.	1180	July 15	DuPont's I. K. D. Density, 1.725; granulation, 2,200.	3	8	Solid band experimental shell; band 3″.3 diameter, 0″.5 wide; beveled front and rear; containing 6¾ ounces musket powder.	13	..	2	......	......	......	From rear and left, 60°. 8 miles an hour.
	1181	July 15		3	8		13	..	2	......	......	......	
	1182	July 15		3	8		13	..	2	......	......	......	
	1183	July 15		3	8		13	..	2	......	......	......	
	1184	July 15		3	8		13	..	4	......	......	......	
	1185	July 15		3	8		13	..	4	......	......	......	
	1186	July 15		3	8		13	..	4	......	......	......	
	1187	July 15		3	8		13	..	4	......	......	......	
	1188	July 15		3	8		13	..	8	......	......	......	From rear and right, 45°.
	1189	July 15		3	8		13	..	8	......	......	......	
	1190	July 15		3	8		13	..	8	......	......	......	
	1191	July 15		3	8		13	..	8	......	......	......	

r., from October 15, 1884, *to September* 15, 1885—Continued.

marks about each fire, such as effect on piece, sound of projectile in flight, scattering of fragments, &c.

Fuze marked C2. Set at 3 seconds; 1½ ounces musket powder bursting charge. Burst 50 feet in front of gun.

Fuze marked B1. Set at 3 seconds; 1½ ounces musket powder bursting charge. Burst in gun.

Fuze marked A2. No plunger or bursting charge. Struck in 8 seconds. One fragment striking short.

Fuze marked B2. No plunger or bursting charge. Broke up in gun. Fuze and brass head recovered down beach intact.

Fuze marked C2. Set at 3 seconds; 6½ ounces bursting charge. Burst in 3¼ seconds.

Fuze marked B2. Set at 3 seconds; 6½ ounces bursting charge. Burst in 2 seconds.

Fuze marked A1. Set at 3 seconds; 6½ ounces bursting charge. Burst in 2¼ seconds.

metallic time-fuzes re- ed from Frankford Ar- l April 21, 1885. (Lead position.)	Fuze set at 3 seconds. Burst in 2½ seconds.

and butt. De Bange gas-check.

osition time fuze set at 3 seconds.	Burst in 2¼ seconds.
osition time fuze set at 3 seconds.	Burst in 2¾ seconds.
time fuze set at 3 seconds.	Burst in 2 seconds.
time fuze set at 3 seconds.	Burst in 1⅞ seconds.
osition time fuze set at 5 seconds.	Burst in 4½ seconds (probably slow in taking time).
osition time fuze set at 5 seconds.	Burst in 3½ seconds.
time fuze set at 5 seconds.	Exploded, prematurely, about 50 yards in front of muzzle.
time fuze set at 5 seconds.	Burst in 3½ seconds.
osition time fuze set at 10 seconds.	Burst in 8 seconds.
osition time fuze set at 10 seconds.	Burst in 9⅞ seconds.
time fuze set at 10 seconds.	Burst in 11¾ seconds.
time fuze set at 10 seconds.	Burst in 12 seconds.

onstantly changed on account of moving vessels.

Record of firing with 3.2-inch breech-loading rifle (steel) at Sandy

	Number of fire.	Time.	Powder. Kind.	Powder. Wgt. Pounds.	Powder. Wgt. Ounces.	Projectile. Kind.	Projectile. Wgt. Pounds.	Projectile. Wgt. Ounces.	Elevation.	Pressure per square inch of bore (Crusher).	Instrumental velocity 100 feet from muzzle.	Recoil.	Wind, strength and direction.
		1885.							° ′	*Lbs.*	*Feet.*	*Feet.*	
A. M.—Barometer, 29.949; thermometer, 73.8; humidity, 69.	1192	July 15	DuPont's I. K. D. Density, 1.725; granulation, 2200.	3	8	Solid band experimental shell; band 3″.3 diameter, 0″.5 wide; beveled front and rear; containing 6¾ ounces musket powder.	13	..	13	......	......	......	From left, 8 miles an hour.
	1193	July 15		3	8		13	..	13	......	......	......	
	1194	July 15		3	8		13	..	13	......	......	......	
	1195	July 15		3	8		13	..	13	......	......	......	
A. M.—Barometer, 30.085; thermometer, 81.3; humidity, 73.	1196	July 17		3	8	Experimental shrapnel received from Watertown Arsenal April 15, 1885.	13	..	4	......	......	......	From rear. 4 miles an hour.
	1197	July 17		3	8		13	..	4	......	......	......	
	1198	July 17		3	8		13	..	0	......	......	......	From rear and right, 87°.
P. M.—Barometer, 30.071; thermometer, 75.4; humidity, 55.	1199	Aug. 6		3	8	Solid band experimental shell; band 3″.3 diameter, 0″.5 wide; beveled front and rear; head of shell cut off and brass head from shrapnel screwed on.	12	..	5	......	......	......	From rear and left, 22°; 8 miles an hour.
	1200	Aug. 6		3	8		12	..	5	......	......	......	
A. M.—Barometer, 30.076; thermometer, 73; humidity, 78.	1201	Sept. 4	DuPont's L. X. B. Density, 1.706; granulation, 270.	3	8	Solid band experimental shell; band 3″.3 diameter, 0″.5 wide; beveled front and rear.	13	..	−15	37,100	1,703	9.00	From front and left, 45°; 15 miles an hour.
	1202	Sept. 4		3	8		13	..	−15	35,900	1,691	9.00	
	1203	Sept. 4		3	8		13	..	−15	35,880	1,684	9.00	
	1204	Sept. 4		3	8		13	..	−15	37,250	1,693	10.00	
	1205	Sept. 4		3	8		13	..	−15	36,700	1,696	10.50	
	1206	Sept. 4		3	8		13	..	−15	32,750	1,640	10.00	
	1207	Sept. 4		3	12		13	..	−15	36,300	1,712	10.00	
	1208	Sept. 4		3	12		13	..	−15	35,900	1,711	10.00	

ok, N. J., from October 15, 1884, to September 15, 1885—Continued.

	Special remarks about each fire, such as effect on piece, sound of projectile in flight, scattering of fragments, &c.	
July 3, 1885.	Composition time fuze set at 15 seconds.	Burst in 15 seconds.
	Composition time fuze set at 15 seconds.	Burst in 15 seconds.
	Brass time fuze set at 15 seconds.	Burst in 15¼ seconds.
	Brass time fuze set at 15 seconds.	Burst in 13¾ seconds.
	Line of fire constantly changed on account of moving vessels.	
	Fired over water to try fuze; composition fuze set at 5 seconds; shrapnel contained 1 4/16 ounces musket powder, bursting charge.	Broke into three fragments, one striking beach 50 yards from gun, one struck water 75 yards from gun, and one struck water in 3½ seconds.
	Fired over water to try fuze; brass fuze set at 5 seconds; shrapnel contained 1 4/16 ounces musket powder, bursting charge.	Broke in three fragments; one struck water in 3 seconds and one in 5 seconds.
	Fired into sand butt to try fuze; brass fuze set at 5 seconds; no bursting charge in shrapnel.	Broke in bore into many fragments; 30 hits counted on boards covering sand butt; fuze and half of base of shrapnel recovered from butt.
	Frankford metallic time fuze set to explode at 5 seconds. Burst 100 yards in front of gun. No small fragments noticed.	
	Frankford metallic time fuze set to explode at 5 seconds. Burst in or near gun. Number of small fragments noticed striking directly in front of gun.	
	Opened and closed easily.	
	Do.	
	Do.	
	Do.	
	Do.	
	Very slight escape of gas. Block opened easily.	
	Considerable escape of gas. Block opened rather hard.	
	No escape of gas. Block opened easily.	

Record of firing with 3.2-inch breech-loading rifle (steel) at

P M—Barometer, 29.965; thermometer, 77; humidity, 76.

Number of fire.	Time.	Powder. Kind.	Powder. Wgt. Pounds.	Powder. Wgt. Ounces.	Projectile. Kind.	Projectile. Wgt. Pounds.	Projectile. Wgt. Ounces.	Elevation.	Pressure, per square inch of bore (Crusher).	Instrumental velocity 100 feet from muzzle.	Recoil.	Wind, strength and direction.
	1885.							° '	Lbs.	Feet.	Feet.	
1209	Sept. 4	Du Pont's L. X. B. Density, 1.706; granulation, 270.	3	8	Solid band experimental shell; band 3".3 diameter, 0".5 wide; beveled front and rear.	13	..	—15	.....	....	10.00	From front and right, 3°; 20 miles an hour.
1210	Sept. 4		3	8		13	..	—15	.....	.....	.....	
1211	Sept. 4		3	8		13	..	—15	.....	.....	.....	
1212	Sept. 4		3	8		13	..	—15	.....	.....	.....	
1213	Sept. 4		3	8		13	..	—15	.....	.....	.....	
1214	Sept. 4		3	8		13	..	—15	.....	.....	.....	
1215	Sept. 4		3	8		13	..	—15	.....	.....	.....	
1216	Sept. 4		3	8		13	..	—15	.....	.....	.....	
1217	Sept. 4		3	8		13	..	—15	.....	.....	.....	
1218	Sept. 4		3	8		13	..	—15	.....	.....	.....	
1219	Sept. 4		3	8		13	..	—15	.....	.....	.....	
1220	Sept. 4		3	8		13	..	—15	.....	.....	.....	
1221	Sept. 4		3	8		13	..	—15	.....	.....	.....	
1222	Sept. 4		3	8		13	..	—15	.....	.....	.....	
1223	Sept. 4		3	8		13	..	—15	.....	.....	.....	
1224	Sept. 4		3	8		13	..	—15	.....	.....	.....	
1225	Sept. 4		3	8		13	..	—15	.....	.....	.....	
1226	Sept. 4		3	8		13	..	—15	.....	.....	.....	
1227	Sept. 4		3	8		13	..	—15	.....	.....	.....	
1228	Sept. 4		3	8		13	..	—15	.....	.....	.....	
1229	Sept. 4		3	8		13	..	—15	.....	.....	.....	
1230	Sept. 4		3	8		13	..	—15	.....	.....	.....	
1231	Sept. 4		3	8		13	..	—15	.....	.....	.....	
1232	Sept. 4		3	8		13	..	—15	.....	.....	.....	
1233	Sept. 4		3	8		13	..	—15	.....	.....	.....	
1234	Sept. 4		3	8		13	..	—15	.....	.....	.....	
1235	Sept. 4		3	8		13	..	—15	.....	.....	.....	
1236	Sept. 4		3	8		13	..	—15	.....	.....	.....	
1237	Sept. 4		3	8		12	..	—15	.....	.....	.....	
1238	Sept. 4		3	8		13	..	—15	.....	.....	.....	
1239	Sept. 4		3	8		13	..	—15	.....	.....	.....	
1240	Sept. 4		3	8		13	..	—15	.....	.....	.....	
1241	Sept. 4		3	8		13	..	—15	.....	.....	.....	
1242	Sept. 4		3	8		13	..	—15	.....	.....	.....	
1243	Sept. 4		3	8		13	..	—15	.....	.....	.....	
1244	Sept. 4		3	8		13	..	—15	.....	.....	.....	

ook, *N. J., from October* 15, 1884, *to September* 15, 1885—Continued.

Special remarks about each fire, such as effect on piece, sound of projectile in flight, scattering of fragments, &c.
Rounds 1209 to 1250 fired in 35 minutes.

Record of firing with 3.2-inch breech-loading rifle (steel) at [illegible]

Number of fire.	Time.	Powder. Kind.	Powder. Wgt. Pounds.	Powder. Wgt. Ounces.	Projectile. Kind.	Projectile. Wgt. Pounds.	Projectile. Wgt. Ounces.	Elevation.	Pressure per square inch of bore (Crusher).	Instrumental velocity 100 feet from muzzle.	Recoil.	Wind, strength and direction.
	1885.							° '	*Lbs.*	*Feet.*	*Feet.*	
1245	Sept. 4	Du Pont's L. X. B. Density, 1.706; granulation, 270.	3	8	[illegible] Solid-band experimental shell; band 3".3 diameter, 0".5 wide; beveled front and rear.	13	..	—15	.....	.....	.....	From front and right, 8°; 20 miles an hour.
1246	Sept. 4		3	8		13	.	—15	.....	.....	.....	
1247	Sept. 4		3	8		13	..	—15	.....	.....	.....	
1248	Sept. 4		3	8		13	..	—15	.....	.....	.....	
1249	Sept. 4		3	8		13	..	—15	.....	.....	.....	
1250	Sept. 4		3	8		13	..	—15	.....	.....	.....	
1251	Sept. 4		3	8		13	..	—15	.....	.....	.....	
1252	Sept. 4		3	8		13	..	—15	.....	.....	.....	
1253	Sept. 4		3	8		13	..	—15	.....	.....	.....	
1254	Sept. 4		3	8		13	..	—15	.....	.....	.....	
1255	Sept. 4		3	8		13	..	—15	.....	.....	.....	
1256	Sept. 4		3	8		13	.	—15	.....	.....	.....	
1257	Sept. 4		3	8		13	..	—15	.....	.....	.....	
1258	Sept. 4		3	8		13	..	—15	.....	.....	.....	
1259	Sept. 4		3	8		13	..	—15	.....	.....	.....	
1260	Sept. 4		3	8		13		—15	.....	.....	.....	
1261	Sept. 4		3	8		13	..	—15	.....	.....	.....	
1262	Sept. 4		3	8		13	..	—15	.....	.....	.....	
1263	Sept. 4		3	8		13	..	—15	.....	.....	.....	
1264	Sept. 4		3	8		13	.	—15	.....	.....	.....	
1265	Sept. 4		3	8		13	..	—15	.....	.....	.....	
1266	Sept. 4		3	8		13	..	—15	.....	.....	.....	
1267	Sept. 4		3	8		13	..	—15	.....	.....	.....	
1268	Sept. 4		3	8		13	..	—15	.....	.....	.....	
1269	Sept. 4		3	8		13	..	—15	.....	.....	.....	
1270	Sept. 4		3	8		13	..	—15	.....	.....	.....	
1271	Sept. 4		3	8		13	..	—15	.....	.....	.....	
1272	Sept. 4		3	8		13	..	—15	.....	.....	.....	
1273	Sept. 4		3	8		13	..	—15	.....	.....	.....	
1274	Sept. 4		3	8		13	..	—15	.....	.....	.....	
1275	Sept. 4		3	8		13	..	—15	.....	.....	.....	
1276	Sept. 4		3	8		13	..	—15	.....	.....	.....	
1277	Sept. 4		3	8		13	..	—15	.....	.....	.....	
1278	Sept. 4		3	8		13	..	—15	.....	.....	.....	
1279	Sept. 4		3	8		13	..	—15	.....	.....	.....	
1280	Sept. 4		3	8		13	..	—15	.....	.....	.....	

P. M.—Barometer, 29.965; thermometer, 77; humidity, 76.

ook, N. J., *from October* 15, 1884, *to September* 15, 1885—Continued.

pecial remarks about each fire, such as effect on piece, sound of projectile in flight, scattering of fragments, &c.
Fired into sand butt. De Bange gas-check. Rounds 1209 to 1250 fired in 35 minutes. Gun wiped out with oil sponge, and formeture cleaned off with waste.

Record of firing with 3.2-inch breech-loading rifle (steel) at

	Number of fire.	Time.	Powder. Kind.	Powder. Wgt Pounds.	Powder. Wgt Ounces.	Projectile. Kind.	Projectile. Wgt Pounds.	Projectile. Wgt Ounces.	Elevation.	Pressure, per square inch of bore (Crusher).	Instrumental velocity 100 feet from muzzle.	Recoil.	Wind, strength and direction.
		1885.							° ′	*Lbs.*	*Feet.*	*Feet.*	
P. M.—Barometer, 29.965; thermometer, 77; humidity, 76.	1281	Sept. 4	DuPont's L. X. B. Density, 1.786; granulation, 270.	3	8	Solid band experimental shell; band, 3″.3 diameter, 0″.5 wide; beveled front and rear.	13	..	15	......	......	......	From front and right; 8°; 20 miles an hour.
	1282	Sept. 4		3	8		13	..	—15	......	......	......	
	1283	Sept. 4		3	8		13	..	—15	......	......	......	
	1284	Sept. 4		3	8		13	..	—15	......	......	......	
	1285	Sept. 4		3	8		13	..	—15	......	......	......	
	1286	Sept. 4		3	8		13	..	—15	......	......	......	
	1287	Sept. 4		3	8		13	..	—15	......	......	......	
	1288	Sept. 4		3	8		13	..	—15	......	......	......	
	1289	Sept. 4		3	8		13	..	—15	......	......	......	
	1290	Sept. 4		3	8		13	..	—15	......	......	......	
	1291	Sept. 4		3	8		13	..	—15	......	......	......	
	1292	Sept. 4		3	8		13	..	—15	......	......	......	
	1293	Sept. 4		3	8		13	..	—15	......	......	......	
	1294	Sept. 4		3	8		13	..	—15	......	......	......	
	1295	Sept. 4		3	8		13	..	—15	......	......	......	
	1296	Sept. 4		3	8		13	..	—15	......	......	......	
	1297	Sept. 4		3	8		13	..	—15	......	......	......	
	1298	Sept. 4		3	8		13	..	—15	......	......	......	
	1299	Sept. 4		3	8		13	..	—15	......	......	......	
	1300	Sept. 4		3	8		13	..	—15	......	......	......	
A. M.—Barometer, 29.954; thermometer, 68; humidity, 80.	1301	Sept. 5		3	12		13	..	—15	......	......	12.00	From rear and right 45°; 10 miles an hour.
	1302	Sept. 5		3	12		13	..	—15	......	......	12.00	
	1303	Sept. 5		3	12		13	..	—15	......	......	12.00	
	1304	Sept. 5		3	12		13	..	—15	......	......	12.00	
	1305	Sept. 5		3	12		13	..	—15	......	......	......	
	1306	Sept. 5		3	12		13	..	—15	......	......	......	
	1307	Sept. 5		3	12		13	..	—15	......	......	......	
	1308	Sept. 5		3	12		13	..	—15	......	......	......	
	1309	Sept. 5		3	12		13	..	—15	......	......	......	
	1310	Sept. 5		3	12		13	..	—15	......	......	......	
	1311	Sept. 5		3	12		13	..	—15	......	......	......	
	1312	Sept. 5		3	12		13	..	—15	......	......	......	
	1313	Sept. 5		3	12		13	..	—15	......	......	......	
	1314	Sept. 5		3	12		13	..	—15	......	......	......	
	1315	Sept. 5		3	12		13	..	—15	......	......	......	
	1316	Sept. 5		3	12		13	..	—15	......	......	......	
	1317	Sept. 5		3	12		13	..	—15	......	......	......	

Hook, N. J., from October 15, 1884, *to September* 15, 1885—Continued.

	Special remarks about each fire, such as effect on piece, sound of projectile in flight, scattering of fragments, &c.
Fired into sand butt. De Bange gas-check.	Rounds 1251-1300 fired in 45 minutes.
	Rounds 1251-1300 asbestos mixture squeezed out somewhat from the rear.
	Gun star gauged.
Fired into sand butt. Freyre gas-check.	Excessive escape of gas, making it necessary to use mallet in opening block.
	About $\frac{5}{1000}$ inch removed from rear face of obturator. Opened little stiff. No escape of gas.
	No escape of gas. Blocks opened and closed easily.

Record of firing with 3.2-inch breech-loading rifle (steel) at Sandy

	Number of fire.	Time.	Powder. Kind.	Powder. Wgt. Pounds.	Powder. Wgt. Ounces.	Projectile. Kind.	Projectile. Wgt. Pounds.	Projectile. Wgt. Ounces.	Elevation.	Pressure, per square inch of bore (Crusher).	Instrumental velocity, 100 feet from muzzle.	Recoil.	Wind, strength and direction.
		1885							° '	*Lbs.*	*Feet.*	*Feet.*	
A. M.—Barometer, 29.954; thermometer, 68; humidity, 80.	1318	Sept. 5	Density, 1.706; granulation, 270.	3	12	d 3".3 diameter, 0".5 wide; beveled front and rear.	13	..	—15	......	......	.....	right, 43°; 10 miles an hour.
	1319	Sept. 5		3	12		13	..	—15	......	......	.....	
	1320	Sept. 5		3	12		13	..	—15	......	......	.....	
	1321	Sept. 5		3	12		13	..	—15	......	......	.....	
	1322	Sept. 5		3	12		13	..	—15	......	....	.....	
	1323	Sept. 5		3	12		13	..	—15	......	......	.....	
	1324	Sept. 5		3	12		13	..	—15	......	......	.....	
	1325	Sept. 5		3	12		13	..	—15	......	......	.....	
	1326	Sept. 5		3	12		13	..	—15	......	......	.....	
	1327	Sept. 5		3	12		13	..	—15	......	......	.....	
	1328	Sept. 5		3	12		13	..	—15	......	......	.....	
	1329	Sept. 5		3	12		13	..	—15	......	......	.....	
	1330	Sept. 5		3	12		13	..	—15	......	......	.....	
	1331	Sept. 5		3	12		13	..	—15	......	......	.....	
	1332	Sept. 5		3	12		13	..	—15	......	......	.....	
	1333	Sept. 5		3	12		13	..	—15	......	......	.....	
	1334	Sept. 5		3	12		13	..	—15	......	......	.....	
	1335	Sept. 5		3	12		13	..	—15	......	......	.....	
	1336	Sept. 5		3	12		13	..	—15	......	......	.....	
	1337	Sept. 5		3	12		13	..	—15	......	......	.....	

Hook, N. J., from October 15, 1884, *to September* 15, 1885—Continued.

Special remarks about each fire, such as effect on piece, sound of projectile in flight, scattering of fragments, &c.
Fired into sand butt. Freyre gas-check.
After this round vent stopped and had to be drilled out.
Fired into sand butt. Freyre gas-check.

Record of firing with 3.2-inch breech-loading rifle (steel) at Sandy

	Number of fire.	Time.	Powder.			Projectile.			Elevation.	Pressure, per square inch of bore (Crusher).	Instrumental velocity 100 feet from muzzle.	Recoil.	Wind, strength and direction.
			Kind.	Wgt Pounds.	Wgt Ounces.	Kind.	Wgt Pounds.	Wgt Ounces.					
		1885.							° ′	*Lbs.*	*Feet.*	*Feet.*	
A. M.—Barometer, 29.954; thermometer, 68; humidity, 80.	1354	Sept. 5	X. B. Density, 1.706; granulation, 270.	3	12	l; band 3".3 diameter, 0".5 wide; beveled front and rear.	13	..	−15	......	......	......	ear and right 43°; 10 miles an hour.
	1355	Sept. 5		3	12		13	..	−15	......	......	......	
	1356	Sept. 5		3	12		13	..	−15	......	......	......	
	1357	Sept. 5		3	12		13	..	−15	......	......	......	
	1358	Sept. 5		3	12		13	..	−15	......	......	......	
	1359	Sept. 5		3	12		13	..	−15	......	......	......	
	1360	Sept. 5		3	12		13	..	−15	......	......	......	
	1361	Sept. 5		3	12		13	..	−15	......	......	......	
	1362	Sept. 5		3	12		13	..	−15	......	......	......	
	1363	Sept. 5		3	12		13	..	−15	......	......	......	
	1364	Sept. 5		3	12		13	..	−15	......	......	......	
	1365	Sept. 5		3	12		13	..	−15	......	......	......	
	1366	Sept. 5		3	12		13	..	−15	......	......	......	
	1367	Sept. 5		3	12		13	..	−15	......	......	......	
	1368	Sept. 5		3	12		13	..	−15	......	......	......	
	1369	Sept. 5		3	12		13	..	−15	......	......	......	
	1370	Sept. 5		3	12		13	..	−15	......	......	......	
	1371	Sept. 5		3	12		13	..	−15	......	......	......	
	1372	Sept. 5		3	12		13	..	−15	......	......	......	
	1373	Sept. 5		3	12		13	..	−15	......	......	......	

Hook. N. J., from October 15, 1884, *to September* 15, 1885—Continued.

Special remarks about each fire, such as effect on piece, sound of projectile in flight, scattering of fragments, &c.
Fired into sand butt. Freyre gas-check. Rounds 1362 to 1386 fired in 18 minutes.
Trail of carriage bent and cracked, and seven rivets broken off.

Record of firing with 3.2-inch breech-loading rifle (steel) at Sandy

	Number of fire.	Time.	Powder. Kind.	Powder. Wgt Pounds.	Powder. Wgt Ounces.	Projectile. Kind.	Projectile. Wgt Pounds.	Projectile. Wgt Ounces.	Elevation.	Pressure, per square inch of bore (Crusher).	Instrumental velocity 100 feet from muzzle.	Recoil.	Wind, strength and direction.
		1885.							°. ′	*Lbs.*	*Feet.*	*Feet.*	
	1387	Sept. 11	DuPont's I. X. B. Density, 1.706; granulation, 270.	3	12	Solid ½-inch band.	13	..	0	34,000	1,746	.....	From rear and left. 45°; 18 miles an hour.
	1388	Sept. 11		3	12		13	..	0	35,550	1,748	.....	
	1389	Sept. 11		3	12		13	..	0	34,250	1,727	.....	
	1390	Sept. 11		3	12		13	..	0	......	.....	.....	
	1391	Sept. 11		3	12		13	..	0	......	.....	.....	
	1392	Sept. 11		3	12		13	..	0	......	.....	.....	
	1393	Sept. 11		3	12		13	..	0	......	.....	.....	
	1394	Sept. 11		3	12		13	..	0	......	.....	.....	
	1395	Sept. 11		3	12		13	..	0	......	.....	.....	
	1396	Sept. 11		3	12		13	..	0	......	.....	.....	
	1397	Sept. 11		3	12		13	..	0	......	.....	.....	
	1398	Sept. 11		3	12		13	..	0	......	.....	.....	
	1399	Sept. 11		3	12		13	..	0	......	.....	.....	
	1400	Sept. 11		3	12		13	..	0	......	.....	.....	
	1401	Sept. 11		3	12		13	..	0	......	.....	.....	
	1402	Sept. 11		3	12		13	..	0	......	.....	.....	
	1403	Sept. 11		3	12		13	..	0	......	.....	.....	
A. M.—Barometer, 30.300; thermometer, 64; humidity, 81.	1404	Sept. 11		3	12		13	..	0	......	.....	.....	
	1405	Sept. 11		3	12		13	..	0	......	.....	.....	
	1406	Sept. 11		3	12		13	..	0	......	.....	.....	
	1407	Sept. 11		3	12		13	..	0	......	.....	.....	
	1408	Sept. 11		3	12		13	..	0	......	.....	.....	
	1409	Sept. 11		3	12		13	..	0	......	.....	.....	
	1410	Sept. 11		3	12		13	..	0	......	.....	.....	
	1411	Sept. 11		3	12		13	..	0	......	.....	.....	
	1412	Sept. 11		3	12		13	..	0	......	.....	.....	
	1413	Sept. 11		3	12		13	..	0	......	.....	.....	
	1414	Sept. 11		3	12		13	..	0	......	.....	.....	
	1415	Sept. 11		3	12		13	..	0	......	.....	.....	
	1416	Sept. 11		3	12		13	..	0	......	.....	.....	
	1417	Sept. 11		3	12		13	..	0	......	.....	.....	
	1418	Sept. 11		3	12		13	..	0	......	.....	.....	
	1419	Sept. 11		3	12		13	..	0	......	.....	.....	
	1420	Sept. 11		3	12		13	..	0	......	.....	.....	
	1421	Sept. 11		3	12		13	..	0	......	.....	.....	
	1422	Sept. 11		3	12		13	..	0	......	.....	.....	

Hook, N. J., from October 15, 1884, *to September* 15, 1885—Continued.

Special remarks about each fire, such as effect on piece, sound of projectile in flight, scattering of fragments, &c.
Fired into sand butt. Freyre gas-check.
Bolt of elevating screw box broke.
Fired in 11 minutes.
Assembling bolts for axle plates broke and had to be repaired.

Record of firing with 3.2-inch breech-loading rifle (steel) at Sandy

	Number of fire.	Time.	Powder. Kind.	Powder. Wgt Pounds.	Powder. Wgt Ounces.	Projectile. Kind.	Projectile. Wgt Pounds.	Projectile. Wgt Ounces.	Elevation.	Pressure per square inch of bore (Crusher).	Instrumental velocity 100 feet from muzzle.	Recoil.	Wind, strength and direction.
		1885.							° ′	*Lbs.*	*Feet.*	*Feet.*	
A. M.—Barometer, 30.260; thermometer, 64; humidity, 81.	1423	Sept. 11	DuPont's L. X. R. Density 1.706; granulation, 270.	3	12	Solid ½-inch band.	13	..	0	......	......	.....	From rear and left 45°, 16 miles an hour.
	1424	Sept. 11		3	12		13	..	0	......	......	.....	
	1425	Sept. 11		3	12		13	..	0	......	......	.....	
	1426	Sept. 11		3	12		13	..	0	......	......	.....	
	1427	Sept. 11		3	12		13	..	0	......	......	.....	
	1428	Sept. 11		3	12		13	..	0	......	......	.....	
	1429	Sept. 11		3	12		13	..	0	......	......	.....	
	1430	Sept. 11		3	12		13	..	0	......	......	.....	
	1431	Sept. 11		3	12		13	..	0	......	......	.....	
	1432	Sept. 11		3	12		13	..	0	......	......	.....	
	1433	Sept. 11		3	12		13	..	0	......	......	.....	
	1434	Sept. 11		3	12		13	..	0	......	......	.....	
	1435	Sept. 11		3	12		13	..	0	......	......	.....	
	1436	Sept. 11		3	12		13	..	0	......	......	.....	
	1437	Sept. 11		3	12		13	..	0	......	......	.....	
	1438	Sept. 11		3	12		12	..	0	......	......	.....	
	1439	Sept. 11		3	12		13	..	0	......	......	.....	
	1440	Sept. 11		3	12		13	..	0	......	......	.....	
	1441	Sept. 11		3	12		13	..	0	......	......	.....	
	1442	Sept. 11		3	12		13	..	0	......	......	.....	
	1443	Sept. 11		3	12		13	..	0	......	......	.....	
	1444	Sept. 11		3	12		13	..	0	......	......	.....	
	1445	Sept. 11		3	12		13	..	0	......	......	.....	
	1446	Sept. 11		3	12		13	..	0	......	......	.....	
	1447	Sept. 11		3	12		13	..	0	......	......	.....	
	1448	Sept. 11		3	12		13	..	0	......	......	.....	
	1449	Sept. 11		3	12		13	..	0	......	......	.....	
	1450	Sept. 11		3	12		13	.	0	......	......	.....	
	1451	Sept. 11		3	12		13	.	0	......	......	.....	
	1452	Sept. 11		3	12		13	..	0	......	......	.....	
	1453	Sept. 11		3	12		13	..	0	......	......	.....	
	1454	Sept. 11		3	12		13	..	0	......	......	.....	
	1455	Sept. 11		3	12		13	..	0	......	......	.....	
	1456	Sept. 11		3	12		13	..	0	......	......	.....	
	1457	Sept. 11		3	12		13	..	0	......	......	.....	

Hook, N. J., from October 15, 1884, *to September* 15, 1885—Continued.

Special remarks about each fire, such as effect on piece, sound of projectile in flight, scattering of fragments, &c.

Record of firing with 3.2-inch breech-loading rifle (steel) at Sandy

	Number of fire.	Time.	Powder. Kind.	Powder. Wgt Pounds.	Powder. Wgt Ounces.	Projectile. Kind.	Projectile. Wgt Pounds.	Projectile. Wgt Ounces.	Elevation.	Pressure, per square inch of bore (Crusher).	Instrumental velocity 100 feet from muzzle.	Recoil.	Wind, strength and direction.
		1885.							° '	*Lbs.*	*Feet.*	*Feet.*	
A. M.—Barometer, 30.260; thermometer, 64; humidity, 81.	1458	Sept. 11	Du Pont's L. X. B. Density, 1.706; granulation, 270.	3	12	Solid ⅜-inch band.	13	..	0	......	......	.....	From rear and left 49°; 16 miles an hour.
	1459	Sept. 11		3	12		13	..	0	......	......	.....	
	1460	Sept. 11		3	12		13	..	0	......	......	.....	
	1461	Sept. 11		3	12		13	..	0	......	......	.....	
	1462	Sept. 11		3	12		13	..	0	......	......	.....	
	1463	Sept. 11		3	12		13	..	0	......	......	.....	
	1464	Sept. 11		3	12		13	..	0	......	......	.....	
	1465	Sept. 11		3	12		13	..	0	......	......	.....	
	1466	Sept. 11		3	12		13	..	0	......	......	.....	
	1467	Sept. 11		3	12		13	..	0	......	......	.....	
	1468	Sept. 11		3	12		13	..	0	......	......	.....	
	1469	Sept. 11		3	12		13	..	0	......	......	.....	
	1470	Sept. 11		3	12		13	..	0	......	......	.....	
	1471	Sept. 11		3	12		13	..	0	......	......	.....	
	1472	Sept. 11		3	12		13	..	0	......	......	.....	
	1473	Sept. 11		3	12		13	..	0	......	......	.....	
	1474	Sept. 11		3	12		13	..	0	......	......	.....	
	1475	Sept. 11		3	12		13	..	0	......	......	.....	
	1476	Sept. 11		3	12		13	..	0	......	......	.....	
	1477	Sept. 11		3	12		13	..	0	......	......	.....	
	1478	Sept. 11		3	12		13	..	0	......	......	.....	
	1479	Sept. 11		3	12		13	..	0	......	......	.....	
	1480	Sept. 11		3	12		13	..	0	......	......	.....	
	1481	Sept. 11		3	12		13	..	0	......	......	.....	
	1482	Sept. 11		3	12		13	..	0	......	......	.....	
	1483	Sept. 11		3	12		13	..	0	......	......	.....	
P. M.—Barometer, 30.225; thermometer, 68; humidity, 68.	1484	Sept. 11		3	12		13	..	0	34, 900	1, 750	.....	From front and right 67°; 7 miles an hour.
	1485	Sept. 11		3	12		13	..	0	35, 000	1, 749	.....	
	1486	Sept. 11		3	12		13	..	0	35, 330	1, 747	.....	
	1487	Sept. 11		3	12		13	..	0	......	......	.....	
	1488	Sept. 11		3	12		13	..	0	......	......	.....	
	1489	Sept. 11		3	12		13	..	0	......	......	.....	
	1490	Sept. 11		3	12		13	..	0	......	......	.....	
	1491	Sept. 11		3	12		13	..	0	......	......	.....	
	1492	Sept. 11		3	12		13	..	0	......	......	.....	
	1493	Sept. 11		3	12		13	..	0	......	......	.....	

Hook, N. J., from October 15, 1884, *to September* 15, 1885—Continued.

	Special remarks about each fire, such as effect on piece, sound of projectile in flight, scattering of fragments, &c.
Fired into sand butt. Freyre gas-check.	Block jammed in carrier.
	Rounds 1412–1483 fired in 47 minutes.
	Block stuck after firing and opened with difficulty; working parts wiped out with oiled waste.
utt. Freyre gas-check.	Gun star-gauged.
	Rounds 1487–1536 fired in 32 minutes.

Record of firing with 3.2-inch breech-loading rifle (steel) at Sandy

P. M.—Barometer, 30.225; thermometer, 68; humidity, 68.

Number of fire.	Time.	Powder. Kind.	Powder. Wgt Pounds.	Powder. Wgt Ounces.	Projectile. Kind.	Projectile. Wgt Pounds.	Projectile. Wgt Ounces.	Elevation.	Pressure per square inch of bore (Crusher).	Instrumental velocity 160 feet from muzzle.	Recoil.	Wind, strength and direction.
	1885.							° ′	*Lbs.*	*Feet.*	*Feet.*	
1494	Sept. 11	DuPont's L. X. R. Density, 1.706; granulation, 270.	3	12	Solid ½-inch band.	13	..	0	......	......	......	From front and right, 87°; 7 miles an hour.
1495	Sept. 11		3	12		13	..	0	......	......	......	
1496	Sept. 11		3	12		13	..	0	......	......	......	
1497	Sept. 11		3	12		13	..	0	......	......	......	
1498	Sept. 11		3	12		13	..	0	......	......	......	
1499	Sept. 11		3	12		13	..	0	......	......	......	
1500	Sept. 11		3	12		13	..	0	......	......	......	
1501	Sept. 11		3	12		13	..	0	......	......	......	
1502	Sept. 11		3	12		13	..	0	......	......	......	
1503	Sept. 11		3	12		13	..	0	......	......	......	
1504	Sept. 11		3	12		13	..	0	......	......	......	
1505	Sept. 11		3	12		13	..	0	......	......	......	
1506	Sept. 11		3	12		13	..	0	......	......	......	
1507	Sept. 11		3	12		13	..	0	......	......	......	
1508	Sept. 11		3	12		13	..	0	......	......	......	
1509	Sept. 11		3	12		13	..	0	......	......	......	
1510	Sept. 11		3	12		13	..	0	......	......	......	
1511	Sept. 11		3	12		13	..	0	......	......	......	
1512	Sept. 11		3	12		13	..	0	......	......	......	
1513	Sept. 11		3	12		13	..	0	......	......	......	
1514	Sept. 11		3	12		13	..	0	......	......	......	
1515	Sept. 11		3	12		13	..	0	......	......	......	
1516	Sept. 11		3	12		13	..	0	......	......	......	
1517	Sept. 11		3	12		13	..	0	......	......	......	
1518	Sept. 11		3	12		13	..	0	......	......	......	
1519	Sept. 11		3	12		13	..	0	......	......	......	
1520	Sept. 11		3	12		13	..	0	......	......	......	
1521	Sept. 11		3	12		13	..	0	......	......	......	
1522	Sept. 11		3	12		13	..	0	......	......	......	
1523	Sept. 11		3	12		13	..	0	......	......	......	
1524	Sept. 11		3	12		13	..	0	......	......	......	
1525	Sept. 11		3	12		13	..	0	......	......	......	
1526	Sept. 11		3	12		13	..	0	......	......	......	
1527	Sept. 11		3	12		13	..	0	......	......	......	
1528	Sept. 11		3	12		13	..	0	......	......	......	
1529	Sept. 11		3	12		13	..	0	......	......	......	

Hook, N. J., from October 15, 1884, *to September* 15, 1885—Continued.

	Special remarks about each fire, such as effect on piece, sound of projectile in flight, scattering o fragments, &c.
Fired into sand butt. Freyre gas-check.	Rounds 1487–1536 fired in 32 minutes.

Record of firing with 3.2-inch breech-loading rifle (steel) at Sand

P. M.—Barometer, 30.225; thermometer, 68; humidity, 68.

Number of fire.	Time.	Powder. Kind.	Powder. Wgt Pounds.	Powder. Wgt Ounces.	Projectile. Kind.	Projectile. Wgt Pounds.	Projectile. Wgt Ounces.	Elevation.	Pressure per square inch of bore (Crusher).	Instrumental velocity 100 feet from muzzle.	Recoil.	Wind, strength and direction.
	1885.							° '	Lbs.	Feet.	Feet.	
1530	Sept. 11	DuPont's L. X. R. Density, 1.706; granulation, 270.	3	12	Solid ½-inch band.	13	..	0	......	......	......	From front and right 270; 7 miles an hour.
1531	Sept. 11		3	12		13	..	0	......	......	......	
1532	Sept. 11		3	12		13	..	0	......	......	......	
1533	Sept. 11		3	12		13	..	0	......	......	......	
1534	Sept. 11		3	12		13	..	0	......	......	......	
1535	Sept. 11		3	12		13	..	0	......	......	......	
1536	Sept. 11		3	12		13	..	0	......	......	......	
1537	Sept. 11		3	12		13	..	0	......	......	......	
1538	Sept. 11		3	12		13	..	0	......	......	......	
1539	Sept. 11		3	12		13	..	0	......	......	......	
1540	Sept. 11		3	12		13	..	0	......	......	......	
1541	Sept. 11		3	12		13	..	0	......	......	......	
1542	Sept. 11		3	12		13	..	0	......	......	......	
1543	Sept. 11		3	12		13	..	0	......	......	......	
1544	Sept. 11		3	12		13	..	0	......	......	......	
1545	Sept. 11		3	12		13	..	0	......	......	......	
1546	Sept. 11		3	12		13	..	0	......	......	......	
1547	Sept. 11		3	12		13	..	0	......	......	......	
1548	Sept. 11		3	12		13	..	0	......	......	......	
1549	Sept. 11		3	12		13	..	0	......	......	......	
1550	Sept. 11		3	12		13	..	0	......	......	......	
1551	Sept. 11		3	12		13	..	0	......	......	......	
1552	Sept. 11		3	12		13	..	0	......	......	......	
1553	Sept. 11		3	12		13	..	0	......	......	......	
1554	Sept. 11		3	12		13	..	0	......	......	......	
1555	Sept. 11		3	12		13	..	0	......	......	......	
1556	Sept. 11		3	12		13	..	0	......	......	......	
1557	Sept. 11		3	12		13	..	0	......	......	......	
1558	Sept. 11		3	12		13	..	0	......	......	......	
1559	Sept. 11		3	12		13	..	0	......	......	......	
1560	Sept. 11		3	12		13	..	0	......	......	......	
1561	Sept. 11		3	12		13	..	0	......	......	......	
1562	Sept. 11		3	12		13	..	0	......	......	......	
1563	Sept. 11		3	12		13	..	0	......	......	......	
1564	Sept. 11		3	12		13	..	0	......	......	......	
1565	Sept. 11		3	12		13	..	0	......	......	......	

Hook, N. J., from October 15, 1884, *to September* 15, 1885—Continued.

Special remarks about each fire, such as effect on piece, sound of projectile in flight, scattering of fragments, &c.
Rounds 1487-1536 fired in 32 minutes.
Fired into sand butt. Freyre gas-check.
Rounds 1537-1586 fired in 25 minutes.

Record of firing with 3.2-inch breech-loading rifle (steel) at Sa

	Number of fire.	Time.	Powder. Kind.	Powder. Wgt. Pounds.	Powder. Wgt. Ounces.	Projectile. Kind.	Projectile. Wgt. Pounds.	Projectile. Wgt. Ounces.	Elevation.	Pressure, per square inch of bore (Crusher).	Instrumental velocity, 100 feet from muzzle.	Recoil.	Wind strength and di
		1885.							° '	*Lbs.*	*Feet.*	*Feet.*	
	1566	Sept. 11	Du Pont's L. X. B. Density, 1.706; granulation, 270.	3	12	Solid ½-inch band.	13	..	0				From front and right 87°, 7 miles an hour
	1567	Sept. 11		3	12		13	..	0				
	1568	Sept. 11		3	12		13	..	0				
	1569	Sept. 11		3	12		13	..	0				
	1570	Sept. 11		3	12		13	..	0				
	1571	Sept. 11		3	12		13	..	0				
	1572	Sept. 11		3	12		13	..	0				
	1573	Sept. 11		3	12		13	..	0				
	1574	Sept. 11		3	12		13	..	0				
P. M.—Barometer, 30.225; thermometer, 68; humidity, 68.	1575	Sept. 11		3	12		13	..	0				
	1576	Sept. 11		3	12		13	..	0				
	1577	Sept. 11		3	12		13	..	0				
	1578	Sept. 11		3	12		13	..	0				
	1579	Sept. 11		3	12		13	..	0				
	1580	Sept. 11		3	12		13	..	0				
	1581	Sept. 11		3	12		13	..	0				
	1582	Sept. 11		3	12		13	..	0				
	1583	Sept. 11		3	12		13	..	0				
	1584	Sept. 11		3	12		13	..	0				
	1585	Sept. 11		3	12		13	..	0				
	1586	Sept. 11		3	12		13	..	0				
	1587	Sept. 12		3	12		13	..	0				From rear and right 68°, 4 miles an hour.
	1588	Sept. 12		3	12		13	..	0				
	1589	Sept. 12		3	12		13	..	0				
	1590	Sept. 12		3	12		13	..	0				
	1591	Sept. 12		3	12		13	..	0				
	1592	Sept. 12		3	12		13	..	0				
A. M.—Barometer, 30.256; thermometer, 65; humidity, 82.	1593	Sept. 12		3	12		13	..	0				
	1594	Sept. 12		3	12		13	..	0				
	1595	Sept. 12		3	12		13	..	0				
	1596	Sept. 12		3	12		13		0				
	1597	Sept. 12		3	12		13	..	0				
	1598	Sept. 12		3	12		13	..	0				
	1599	Sept. 12		3	12		13	..	0				
	1600	Sept. 12		3	12		13	..	0				
	1601	Sept. 12		3	12		13	..	0				

ok, *N. J., from October* 15, 1884, *to September* 15, 1885—Continued.

	Special remarks about each fire, such as effect on piece, sound of projectile in flight, scattering of fragments, &c.
Fired into sand butt. Freyre gas-check.	Rounds 1537-1586 fired in 25 minutes.

UofM

Record of firing with 3.2 inch breech-loading rifle (steel) at Sandy

A. M.—Barometer, 30.56; thermometer, 65; humidity, 82.

Number of fire.	Time.	Powder. Kind.	Powder. Wgt. Pounds.	Powder. Wgt. Ounces.	Projectile. Kind.	Projectile. Wgt. Pounds.	Projectile. Wgt. Ounces.	Elevation.	Pressure per square inch of bore (Crusher).	Instrumental velocity 100 feet from muzzle.	Recoil.	Wind, strength and direction.
	1885.							° ′	*Lbs.*	*Feet.*	*Feet.*	
1602	Sept. 12	Du Pont's I. X. B. Density, 1.766; granulation, 270.	3	12	Solid ½-inch band	13	..	0	......	...	...	From rear and right 45°, 4 miles an hour
1603	Sept. 12		3	12		13	..	0	......	..	...	
1604	Sept. 12		3	12		13	..	0	......	...	..	
1605	Sept. 12		3	12		13	..	0	......	...		
1606	Sept. 12		3	12		13	..	0	......	....	....	
1607	Sept. 12		3	12		13	..	0	......	...	..	
1608	Sept. 12		3	12		13	..	0	......	...	.	
1609	Sept. 12		3	12		13	..	0	......	....	....	
1610	Sept. 12		3	12		13	..	0	......	.	.	
1611	Sept. 12		3	12		13	..	0	......	....	..	
1612	Sept. 12		3	12		13	..	0	......	..	...	
1613	Sept. 12		3	12		13	..	0	......	....	.	
1614	Sept. 12		3	12		13	..	0	......	..	.	
1615	Sept. 12		3	12		13	..	0	......	.	....	
1616	Sept. 12		3	12		13	..	0	......	....	.....	
1617	Sept. 12		3	12		13	..	0	......	....	.....	
1618	Sept. 12		3	12		13	..	0	......	....	....	
1619	Sept. 12		3	12		13	..	0	......	....	..	
1620	Sept. 12		3	12		13	..	0	......	....	..	
1621	Sept. 12		3	12		13	..	0	...	...	.....	
1622	Sept. 12		3	12		13	..	0	......	...	....	
1623	Sept. 12		3	12		13	..	0	....	.	....	
1624	Sept. 12		3	12		13	..	0	......		.	
1625	Sept. 12		3	12		13	..	0	......	....	...	
1626	Sept. 12		3	12		13	..	0	......	..	....	
1627	Sept. 12		3	12		13	..	0	.....	....	...	
1628	Sept. 12		3	12		13	..	0	...	..	...	
1629	Sept. 12		3	12		13	..	0	...	...	...	
1630	Sept. 12		3	12		13	..	0	.....	..	...	
1631	Sept. 12		3	12		13	..	0	....	...	.	
1632	Sept. 12		3	12		13	..	0	......	....	..	
1633	Sept. 12		3	12		13	..	0	......	..	...	
1634	Sept. 12		3	12		13	..	0	......	.	..	
1635	Sept. 12		3	12		13	..	0	.....	..	..	

Hook, N. J., from

Special remarks about each fire, such as effect on piece, s fragments, &c.
Fired into sand butt. Freyre gas-check. Rounds 1587 to 1636 fired in 28½ minutes.

Record of firing with 3.2-inch breech-loading rifle (steel) at Sand

	Number of fire.	Time.	Powder.			Projectile.			Elevation.	Pressure per square inch of bore (Crusher).	Instrumental velocity 100 feet from muzzle.	Recoil.	Wind, strength and direction.
			Kind.	Wgt Pounds.	Wgt Ounces.	Kind.	Wgt Pounds.	Wgt Ounces.					
		1885.							° ′	*Lbs.*	*Feet.*	*Feet.*	
P. M.—Barometer, 30.214; thermometer, 71; humidity, 72	1636	Sept. 12	DuPont's L. X. B. Density, 1.706; granulation, 270.	3	12	Solid ½-inch band.	13	..	0	......	......	......	From front and right 8°; 7 miles an hour.
	1637	Sept. 12		3	12		13	..	0	......	......	......	
	1638	Sept. 12		3	12		13	..	0	......	......	......	
	1639	Sept. 12		3	12		13	..	0	......	......	......	
	1640	Sept. 12		3	12		13	..	0	......	......	......	
	1641	Sept. 12		3	12		13	..	0	......	......	......	
	1642	Sept. 12		3	12		13	..	0	......	......	......	
	1643	Sept. 12		3	12		13	..	0	......	......	......	
	1644	Sept. 12		3	12		13	..	0	......	......	......	
	1645	Sept. 12		3	12		13	..	0	......	......	......	
	1646	Sept. 12		3	12		13	..	0	......	......	......	
	1647	Sept. 12		3	12		13	..	0	......	......	......	
	1648	Sept. 12		3	12		13	..	0	......	......	......	
	1649	Sept. 12		3	12		13	..	0	......	......	......	
	1650	Sept. 12		3	12		13	..	0	......	......	......	
	1651	Sept. 12		3	12		13	..	0	......	......	......	
	1652	Sept. 12		3	12		13	..	0	......	......	......	
	1653	Sept. 12		3	12		13	..	0	......	......	......	
	1654	Sept. 12		3	12		13	..	0	......	......	......	
	1655	Sept. 12		3	12		13	..	0	......	......	......	
	1656	Sept. 12		3	12		13	..	0	......	......	......	
	1657	Sept. 12		3	12		13	..	0	......	......	......	
	1658	Sept. 12		3	12		13	..	0	......	......	......	
	1659	Sept. 12		3	12		13	..	0	......	......	......	
	1660	Sept. 12		3	12		13	..	0	......	......	......	
	1661	Sept. 12		3	12		13	..	0	......	......	......	
	1662	Sept. 12		3	12		13	..	0	......	......	......	
	1663	Sept. 12		3	12		13	..	0	......	......	......	
	1664	Sept. 12		3	12		13	..	0	......	......	......	
	1665	Sept. 12		3	12		13	..	0	......	......	......	
	1666	Sept. 12		3	12		13	..	0	......	......	......	
	1667	Sept. 12		3	12		13	..	0	......	......	......	
	1668	Sept. 12		3	12		13	..	0	......	......	......	
	1669	Sept. 12		3	12		13	..	0	......	......	......	
	1670	Sept. 12		3	12		13	..	0	......	......	......	

POWDER CHAMBER.

nches from breech.	Original diameter.	Enlargement of chamber after—									
		275 rounds.	315 rounds.	459 rounds.	854 rounds.	954 rounds.	1,054 rounds (hot).	1,054 rounds (cold).	1,167 rounds.	1,300 rounds.	1,486 rounds.
	In.	*In.*	*In.*	*In.*	*In.*	*In.*	*In.*	*In.*	*In.*	*In.*	
. 1	3. 768	0. 001	0. 001	0. 002	0. 002	0. 001	0. 021	*0. 011	0. 001	0. 002	
. 2	3. 81	. 005	. 005	. 005	. 004	. 004	. 014	. 006	. 005	. 005	
. 2	3. 755	— . 041	— . 042	— . 042	— . 041	— . 041	— . 037	— . 040	— . 042	— . 041	—

* Due to wearing away of steel around vent bushing.

Record of firing with 3.2-inch breech-loading rifle (steel) at Sandy

	Number of fire.	Time.	Powder.			Projectile.			Elevation.	Pressure per square inch of bore (Crusher).	Instrumental velocity 100 feet from muzzle.	Recoil.	Wind, strength and direction.
			Kind.	Wgt Pounds.	Wgt Ounces.	Kind.	Wgt Pounds.	Wgt Ounces.					
		1885							° '	*Lbs.*	*Feet.*	*Feet.*	
P. M.—Barometer, 30.214; thermometer, 71; humidity, 72.	1671	Sept. 12	DuPont's L. X. B. Density, 1.700; granulation, 270.	3	12	Solid ½-inch band.	13	..	0	.....	.....	.....	From front and right, 8°, 7 miles an hour.
	1672	Sept. 12		3	12		13	..	0	.....	.....	.....	
	1673	Sept. 12		3	12		13	..	0	.....	.....	.....	
	1674	Sept. 12		3	12		13	..	0	.....	.....	.....	
	1675	Sept. 12		3	12		13	..	0	.....	.....	.....	
	1676	Sept. 12		3	12		13	..	0	.....	.....	.....	
	1677	Sept. 12		3	12		13	..	0	.....	.....	.....	
	1678	Sept. 12		3	12		13	..	0	.....	.....	.....	
	1679	Sept. 12		3	12		13	..	0	.....	.....	.....	
	1680	Sept. 12		3	12		13	..	0	.....	.....	.....	
	1681	Sept. 12		3	12		13	..	0	.....	.....	.....	
	1682	Sept. 12		3	12		13	..	0	.....	.....	.....	
	1683	Sept. 12		3	12		13	..	0	.....	.....	.....	
	1684	Sept. 12		3	12		13	..	0	.....	.....	.....	
	1685	Sept. 12		3	12		13	..	0	.....	.....	.....	
	1686	Sept. 12		3	12		13	..	0	.....	.....	.....	
P. M.—Barometer, 29.818; thermometer, 82.4; humidity, 65.	1687	Sept. 15		3	12		13	..	0	.....	.....	.....	From rear and right, 87°, 12 miles an hour.
	1688	Sept. 15		3	12		13	..	0	.....	.....	.....	
	1689	Sept. 15		3	12		13	..	0	.....	.....	.....	
	1690	Sept. 15		3	12		13	..	0	.....	.....	.....	
	1691	Sept. 15		3	12		13	..	0	.....	.....	.....	
	1692	Sept. 15		3	12		13	..	0	.....	.....	.....	
	1693	Sept. 15		3	12		13	..	0	.....	.....	.....	
	1694	Sept. 15		3	12		13	..	0	.....	.....	.....	
	1695	Sept. 15		3	12		13	..	0	.....	.....	.....	
	1696	Sept. 15		3	12		13	..	0	.....	.....	.....	
	1697	Sept. 15		3	12		13	..	0	.....	.....	.....	
	1698	Sept. 15		3	12		13	..	0	.....	.....	.....	
	1699	Sept. 15		3	12		13	..	0	.....	.....	.....	
	1700	Sept. 15		3	12		13	..	0	.....	.....	.....	
	1701	Sept. 15		3	12		13	..	0	.....	.....	.....	
	1702	Sept. 15		3	12		13	..	0	.....	.....	.....	
	1703	Sept. 15		3	12		13	..	0	.....	.....	.....	
	1704	Sept. 15		3	12		13	..	0	.....	.....	.....	
	1705	Sept. 15		3	12		13	..	0	.....	.....	.....	
	1706	Sept. 15		3	12		13	..	0	.....	.....	.....	

V. J., *from October* 15, 1884, *to September* 15, 1885—Continued.

l remarks about each fire, such as effect on piece, sound of projectile in flight, scattering of fragments, &c.

ls 1636 to 1686 fired in 45 minutes.

tar-gauged.

ıto sand butt. Freyre gas-check.

Record of firing with 3.2-inch breech-loading rifle (steel) at Sandy

	Number of fire.	Time.	Powder.			Projectile.			Elevation.	Pressure per square inch of bore (Crusher).	Instrumental velocity 100 feet from muzzle.	Recoil.	Wind, strength and direction.
			Kind.	Wgt Pounds.	Wgt Ounces.	Kind.	Wgt Pounds.	Wgt Ounces.					
		1885.							° ′	Lbs.	Feet.	Feet.	
P. M.—Barometer, 29.818; thermometer, 82.4; humidity, 65.	1707	Sept. 15	DuPont's L. X. B. Density, 1.706; granulation, 270.	3	12	Solid ½-inch band.	13	..	0	......	......	......	From rear and right, 67°; 12 miles an hour.
	1708	Sept. 15		3	12		13	..	0	......	......	......	
	1709	Sept. 15		3	12		13	..	0	......	......	......	
	1710	Sept. 15		3	12		13	..	0	......	......	......	
	1711	Sept. 15		3	12		13	..	0	......	......	......	
	1712	Sept. 15		3	12		13	..	0	......	......	......	
	1713	Sept. 15		3	12		13	..	0	......	......	......	
	1714	Sept. 15		3	12		13	..	0	......	......	......	
	1715	Sept. 15		3	12		13	..	0	......	......	......	
	1716	Sept. 15		3	12		13	..	0	......	......	......	
	1717	Sept. 15		3	12		13	..	0	......	......	......	
	1718	Sept. 15		3	12		13	..	0	......	......	......	
	1719	Sept. 15		3	12		13	..	0	......	......	......	
	1720	Sept. 15		3	12		13	..	0	......	......	......	
	1721	Sept. 15		3	12		13	..	0	......	......	......	
	1722	Sept. 15		3	12		13	..	0	......	......	......	
	1723	Sept. 15		3	12		13	..	0	......	......	......	
	1724	Sept. 15		3	12		13	..	0	......	......	......	
	1725	Sept. 15		3	12		13	..	0	......	......	......	
	1726	Sept. 15		3	12		13	..	0	......	......	......	
	1727	Sept. 15		3	12		13	..	0	......	......	......	
	1728	Sept. 15		3	12		13	..	0	......	......	......	
	1729	Sept. 15		3	12		13	..	0	......	......	......	
	1730	Sept. 15		3	12		13	..	0	......	......	......	
	1731	Sept. 15		3	12		13	..	0	......	......	......	
	1732	Sept. 15		3	12		13	..	0	......	......	......	
	1733	Sept. 15		3	12		13	..	0	......	......	......	
	1734	Sept. 15		3	12		13	..	0	......	......	......	
	1735	Sept. 15		3	12		13	..	0	......	......	......	
	1736	Sept. 15		3	13		13	..	0	......	......	......	
	1737	Sept. 15		3	12		13	..	0	......	......	......	
	1738	Sept. 15		3	12		13	..	0	......	......	......	
	1739	Sept. 15		3	12		13	..	0	......	......	......	
	1740	Sept. 15		3	12		13	..	0	......	......	......	
	1741	Sept. 15		3	12		13	..	0	......	......	......	
	1742	Sept. 15		3	12		13	..	0	......	......	......	

Hook, N. J., from October 15, 1884, *to September* 15, 1885—Continued.

Special remarks about each fire, such as effect on piece, sound of projectile in flight, scattering of fragments, &c.
Fired into sand butt. Freyre gas-check.

Record of firing with 3.2-inch breech-loading rifle (steel) at Sandy

	Number of fire.	Time.	Powder. Kind.	Powder. Wgt. Pounds.	Powder. Wgt. Ounces.	Projectile. Kind.	Projectile. Wgt. Pounds.	Projectile. Wgt. Ounces.	Elevation.	Pressure, per square inch of bore (Crusher).	Instrumental velocity, 100 feet from muzzle.	Recoil.	Wind, strength and direction.
		1885.							° '	*Lbs.*	*Feet.*	*Feet.*	
P. M.—Barometer, 30.225; thermometer, 68; humidity, 68.	1566	Sept. 11	Du Pont's L. X. B. Density, 1.706; granulation, 270.	3	12	Solid ¼-inch band.	13	..	0	......	......	......	From front and right 87°; 7 miles an hour
	1567	Sept. 11		3	12		13	..	0	......	......	......	
	1568	Sept. 11		3	12		13	..	0	......	......	......	
	1569	Sept. 11		3	12		13	..	0	......	......	......	
	1570	Sept. 11		3	12		13	..	0	......	......	......	
	1571	Sept. 11		3	12		13	..	0	......	......	......	
	1572	Sept. 11		3	12		13	..	0	......	......	......	
	1573	Sept. 11		3	12		13	..	0	......	......	......	
	1574	Sept. 11		3	12		13	..	0	......	......	......	
	1575	Sept. 11		3	12		13	..	0	......	......	......	
	1576	Sept. 11		3	12		13	..	0	......	......	......	
	1577	Sept. 11		3	12		13	..	0	......	......	......	
	1578	Sept. 11		3	12		13	..	0	......	......	......	
	1579	Sept. 11		3	12		13	..	0	......	......	......	
	1580	Sept. 11		3	12		13	..	0	......	......	......	
	1581	Sept. 11		3	12		13	..	0	......	......	......	
	1582	Sept. 11		3	12		13	..	0	......	......	......	
	1583	Sept. 11		3	12		13	..	0	......	......	......	
	1584	Sept. 11		3	12		13	..	0	......	......	......	
	1585	Sept. 11		3	12		13	..	0	......	......	......	
	1586	Sept. 11		3	12		13	..	0	......	......	......	
A. M.—Barometer, 30.256; thermometer, 65; humidity, 82.	1587	Sept. 12		3	12		13	..	0	......	......	......	From rear and right 48°; 4 miles an hour.
	1588	Sept. 12		3	12		13	..	0	......	......	......	
	1589	Sept. 12		3	12		13	..	0	......	......	......	
	1590	Sept. 12		3	12		13	..	0	......	......	......	
	1591	Sept. 12		3	12		13	..	0	......	......	......	
	1592	Sept. 12		3	12		13	..	0	......	......	......	
	1593	Sept. 12		3	12		13	..	0	......	......	......	
	1594	Sept. 12		3	12		13	..	0	......	......	......	
	1595	Sept. 12		3	12		13	..	0	......	......	......	
	1596	Sept. 12		3	12		13	..	0	......	......	......	
	1597	Sept. 12		3	12		13	..	0	......	......	......	
	1598	Sept. 12		3	12		13	..	0	......	......	......	
	1599	Sept. 12		3	12		13	..	0	......	......	......	
	1600	Sept. 12		3	12		13	..	0	......	......	......	
	1601	Sept. 12		3	12		13	..	0	......	......	......	

N. J., from October 15, 1884, *to September* 15, 1885—Continued.

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al remarks about each fire, such as effect on piece, sound of projectile in flight, scattering of fragments, &c.

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unds 1537-1586 fired in 25 minutes.

Record of firing with 3.2-inch breech-loading rifle (steel) at Sa

A. M.—Barometer, 30.256; thermometer, 65; humidity, 82.

Number of fire.	Time.	Powder. Kind.	Powder. Wgt. Pounds.	Powder. Wgt. Ounces.	Projectile. Kind.	Projectile. Wgt. Pounds.	Projectile. Wgt. Ounces.	Elevation.	Pressure per square inch of bore (Crusher).	Instrumental velocity 100 feet from muzzle.	Recoil.	Wind, strength and direction.
	1885.							° '	Lbs.	Feet.	Feet.	
1602	Sept. 12	Du Pont's L. X. B. Density, 1.706; granulation, 270.	3	12	Solid ¼-inch band.	13	..	0	......	......	.....	From rear and right 45°, 4 miles an hour.
1603	Sept. 12		3	12		13	..	0	......	......	.....	
1604	Sept. 12		3	12		13	..	0	......	......	.....	
1605	Sept. 12		3	12		13	..	0	......	......	.....	
1606	Sept. 12		3	12		13	..	0	......	......	.....	
1607	Sept. 12		3	12		13	..	0	......	......	.....	
1608	Sept. 12		3	12		13	..	0	......	......	.....	
1609	Sept. 12		3	12		13	..	0	......	......	.....	
1610	Sept. 12		3	12		13	..	0	......	......	.....	
1611	Sept. 12		3	12		13	..	0	......	......	.....	
1612	Sept. 12		3	12		13	..	0	......	......	.....	
1613	Sept. 12		3	12		13	..	0	......	......	.....	
1614	Sept. 12		3	12		13	..	0	......	......	.....	
1615	Sept. 12		3	12		13	..	0	......	......	.....	
1616	Sept. 12		3	12		13	..	0	......	......	.....	
1617	Sept. 12		3	12		13	..	0	......	......	.....	
1618	Sept. 12		3	12		13	..	0	......	......	.....	
1619	Sept. 12		3	12		13	..	0	......	......	.....	
1620	Sept. 12		3	12		13	..	0	......	......	.....	
1621	Sept. 12		3	12		13	..	0	......	......	.....	
1622	Sept. 12		3	12		13	..	0	......	......	.....	
1623	Sept. 12		3	12		13	..	0	......	......	.....	
1624	Sept. 12		3	12		13	..	0	......	......	.....	
1625	Sept. 12		3	12		13	..	0	......	......	.....	
1626	Sept. 12		3	12		13	..	0	......	......	.....	
1627	Sept. 12		3	12		13	..	0	......	......	.....	
1628	Sept. 12		3	12		13	..	0	......	......	.....	
1629	Sept. 12		3	12		13	..	0	......	......	.....	
1630	Sept. 12		3	12		13	..	0	......	......	.....	
1631	Sept. 12		3	12		13	..	0	......	......	.....	
1632	Sept. 12		3	12		13	..	0	......	......	.....	
1633	Sept. 12		3	12		13	..	0	......	......	.....	
1634	Sept. 12		3	12		13	..	0	......	......	.....	
1635	Sept. 12		3	12		13	..	0	......	......	.....	

k, *N. J., from October* 15, 1884, *to September* 15, 1885—Continued.

cial remarks about each fire, such as effect on piece, sound of projectile in flight, scattering of fragments, &c.
ounds 1587 to 1636 fired in 28½ minutes.

Record of firing with 3.2-inch breech-loading rifle (steel) at Sa

	Number of fire.	Time.	Powder. Kind.	Powder. Wgt. Pounds.	Powder. Wgt. Ounces.	Projectile. Kind.	Projectile. Wgt. Pounds.	Projectile. Wgt. Ounces.	Elevation.	Pressure per square inch of bore (Crusher).	Instrumental velocity 100 feet from muzzle.	Recoil.	Wind, strength and direction.
		1885.							° '	*Lbs.*	*Feet.*	*Feet.*	
P. M.—Barometer, 30.214; thermometer, 71; humidity, 72	1636	Sept. 12	DuPont's L. X. B. Density, 1.706; granulation, 270.	3	12	Solid ½-inch band.	13	..	0	......	......	......	From front and right 30°; 7 miles an hour.
	1637	Sept. 12		3	12		13	..	0	......	......	......	
	1638	Sept. 12		3	12		13	..	0	......	......	......	
	1639	Sept. 12		3	12		13	..	0	......	......	......	
	1640	Sept. 12		3	12		13	..	0	......	......	......	
	1641	Sept. 12		3	12		13	..	0	......	......	......	
	1642	Sept. 12		3	12		13	..	0	......	......	......	
	1643	Sept. 12		3	12		13	..	0	......	......	......	
	1644	Sept. 12		3	12		13	..	0	......	......	......	
	1645	Sept. 12		3	12		13	..	0	......	......	......	
	1646	Sept. 12		3	12		13	..	0	......	......	......	
	1647	Sept. 12		3	12		13	..	0	......	......	......	
	1648	Sept. 12		3	12		13	..	0	......	......	......	
	1649	Sept. 12		3	12		13	..	0	......	......	......	
	1650	Sept. 12		3	12		13	..	0	......	......	......	
	1651	Sept. 12		3	12		13	..	0	......	......	......	
	1652	Sept. 12		3	12		13	..	0	......	......	......	
	1653	Sept. 12		3	12		13	..	0	......	......	......	
	1654	Sept. 12		3	12		13	..	0	......	......	......	
	1655	Sept. 12		3	12		13	..	0	......	......	......	
	1656	Sept. 12		3	12		13	..	0	......	......	......	
	1657	Sept. 12		3	12		13	..	0	......	......	......	
	1658	Sept. 12		3	12		13	..	0	......	......	......	
	1659	Sept. 12		3	12		13	..	0	......	......	......	
	1660	Sept. 12		3	12		13	..	0	......	......	......	
	1661	Sept. 12		3	12		13	..	0	......	......	......	
	1662	Sept. 12		3	12		13	..	0	......	......	......	
	1663	Sept. 12		3	12		13	..	0	......	......	......	
	1664	Sept. 12		3	12		13	..	0	......	......	......	
	1665	Sept. 12		3	12		13	..	0	......	......	......	
	1666	Sept. 12		3	12		13	..	0	......	......	......	
	1667	Sept. 12		3	12		13	..	0	......	......	......	
	1668	Sept. 12		3	12		13	..	0	......	......	......	
	1669	Sept. 12		3	12		13	..	0	......	......	......	
	1670	Sept. 12		3	12		13	..	0	......	......	......	

N. J., from October 15, 1884, *to September* 15, 1885—Continued.

d remarks about each fire, such as effect on piece, sound of projectile in flight, sc fragments, &c.

unds 1636 to 1686 fired in 45 minutes.

Record of firing with 3.2-inch breech-loading rifle (steel) at Sa

	Number of fire.	Time.	Powder.			Projectile.			Elevation.	Pressure per square inch of bore (Crusher).	Instrumental velocity 100 feet from muzzle.	Recoil.	Wind, strength and direction.
			Kind.	Wgt. Pounds.	Wgt. Ounces.	Kind.	Wgt. Pounds.	Wgt. Ounces.					
		1885							° ′	Lbs.	Feet.	Feet.	
	1671	Sept. 12	DuPont's L. X. B. Density, 1.706; granulation, 270.	3	12	Solid ¼-inch band.	13	..	0	......	......	......	From front and right, 3°, 7 miles an hour.
	1672	Sept. 12		3	12		13	..	0	......	......	......	
	1673	Sept. 12		3	12		13	..	0	......	......	......	
	1674	Sept. 12		3	12		13	..	0	......	......	......	
	1675	Sept. 12		3	12		13	..	0	......	......	......	
	1676	Sept. 12		3	12		13	..	0	......	......	......	
	1677	Sept. 12		3	12		13	..	0	......	......	......	
P. M.—Barometer, 30.214; thermometer, 71; humidity, 72.	1678	Sept. 12		3	12		13	..	0	......	......	......	
	1679	Sept. 12		3	12		13	..	0	......	......	......	
	1680	Sept. 12		3	12		13	..	0	......	......	......	
	1681	Sept. 12		3	12		13	..	0	......	......	......	
	1682	Sept. 12		3	12		13	..	0	......	......	......	
	1683	Sept. 12		3	12		13	..	0	......	......	......	
	1684	Sept. 12		3	12		13	..	0	......	......	......	
	1685	Sept. 12		3	12		13	..	0	......	......	......	
	1686	Sept. 12		3	12		13	..	0	......	......	......	
	1687	Sept. 15		3	12		13	..	0	......	......	......	From rear and right, 87°, 12 miles an hour.
	1688	Sept. 15		3	12		13	..	0	......	......	......	
	1689	Sept. 15		3	12		13	..	0	......	......	......	
	1690	Sept. 15		3	12		13	..	0	......	......	......	
	1691	Sept. 15		3	12		13	..	0	......	......	......	
	1692	Sept. 15		3	12		13	..	0	......	......	......	
	1693	Sept. 15		3	12		13	..	0	......	......	......	
	1694	Sept. 15		3	12		13	..	0	......	......	......	
	1695	Sept. 15		3	12		13	..	0	......	......	......	
P. M.—Barometer, 29.818; thermometer, 82.4; humidity, 65.	1696	Sept. 15		3	12		13	..	0	......	......	......	
	1697	Sept. 15		3	12		13	..	0	......	......	......	
	1698	Sept. 15		3	12		13	..	0	......	......	......	
	1699	Sept. 15		3	12		13	..	0	......	......	......	
	1700	Sept. 15		3	12		13	..	0	......	......	......	
	1701	Sept. 15		3	12		13	..	0	......	......	......	
	1702	Sept. 15		3	12		13	..	0	......	......	......	
	1703	Sept. 15		3	12		13	..	0	......	......	......	
	1704	Sept. 15		3	12		13	..	0	......	......	......	
	1705	Sept. 15		3	12		13	..	0	......	......	......	
	1706	Sept. 15		3	12		13	..	0	......	......	......	

N. J., from October 15, 1884, to September 15, 1885—Continued.

ecial remarks about each fire, such as effect on piece, s fragments, &c.

unds 1636 to 1686 fired in 45 minutes.

un star-gauged.

d into sand butt. Freyre gas-check.

Top of frame 1 inch by 4 inches iron; bottom of frame one-half inch by 4 inches iron; slot in one side for bolt of lock. Four anchors on each side of door frame three-eighths inches by 2 inches iron, 18 inches long, angle to center of wall: each anchor bolted to frame with two one-fourth inch bolts; heads countersunk, one-half inch round iron pin 10 inches long in anchor in center of wall.

Two iron doors.

Frames one-half inch by 2 inches iron, covered on the outside with best sheet-iron, No. 14 wire gauge, and on the inside with No. 16 corrugated sheet-iron, the inside sheet cut even with the frame; the outside sheet extends one inch around the entire door and laps on door frame, the two sheets riveted together through the frame every three inches. Three straps for hinges extend the whole width of the door and are bolted to same with nine bolts, one-fourth inch in each strap, one eyebolt on the outside, at the bottom of each door, 1 inch diameter, one-fourth inch iron. One heavy lock on each door 6 by 8 inches, with wrought iron case, six tumblers, brass bolt and guards, and two brass keys for each lock. One oval drop handle on each door, three-eighths inch brass, oval 2 by 4 inches.

Eight iron window frames.

Inside measurement, 4 feet wide, 7 feet maximum, 6 feet 8 inches minimum height. Angle iron of same dimensions as that used in the door frames; three anchors on each side of window frames; the anchors the same as the door-frame anchors: two holes five-eighths inch square in the window frames, on each at top and bottom.

Sixteen iron shutters; two for each window.

The frame for shutters one-half by 2-inch iron, covered on the outside with No. 14 sheet-iron and on the inside with iron of the same gauge, corrugated. The outside sheet projects one inch, as in the doors, except the left-hand shutter of each window. The outside sheet is cut back on frame one inch in the center of the window for the right-hand shutter to close over; (right and left estimated from the inside of building.) Two strap hinges on each shutter, bolted through the same as the doors; one eyebolt on each shutter on the bottom and outside; one catch on each shutter for swing bar. On each right-hand shutter two spring store-door bolts one-half inch square, 18 inches long, one at the top and one at the bottom; one swing bar with small knob on one end, iron three-eighths inch by 2 inches, and 24 inches long. One ring 3 inches in diameter of one-fourth inch round iron.

Galvanized iron roof.

The roof on each side measures 29 feet 6¼ inches by 203 feet 3 inches.

Eleven iron purlins between rafters on each side 4 inches high, flange 2 inches, the distance between purlins being 33¾ inches from center to center. The iron for the roof is of the best bloom sheet-iron No. 20 wire gauge, corrugated and galvanized; the depth of corrugation is three-fourths inch, sheets 3 feet by 7 feet 3 inches, and well fastened together by tinned-iron rivets on the upper corrugations. The sheets lap 1¼ inches on both sides and ends, and strips of canvas dipped in oil and white lead are laid between the joints, making them impervious to air and water.

The roof is fastened to the purlins by a galvanized-iron U-shaped strap one-eighth inch by three-fourths of an inch, and 14½ inches long, bolted to the upper corrugations on each side of the purlins and carried under and around the purlins. The ridge of the roof is finished by a roll 3½ inches in diameter, bolted to the roof. A cornice is fastened to the roof on each end of the building, making four pieces, each 29 feet 6 inches long, 5 inches by 5 inches.

The eaves-trough extends on each side of the building its entire length, making two troughs each 204 feet 1 inch long by 13 inches wide and varying in depth from 4½ inches to 10½ inches, to fit hooks, and is well soldered to the roof and finished on the outer edge by a quarter inch round iron formed in the edge of the eaves-trough. The sheets are joined together to carry the water to the center and to each end of the building, each section being 51 feet with 6 inches fall in section.

The eaves-trough hooks are made of three-eighths inch by 2-inch iron, and are bolted to the purlins and held in place by a flat bar of iron one-fourth of an inch by 1½ inch, running the entire length of the building. The two lower purlins are connected by five-eighths inch iron bolts 34 inches long, every 5 feet, to carry the eaves-trough. Under the eaves-trough and on the outer edge of the brick wall is a drip of angle sheet-iron 1 inch by 1½ inches, soldered to the eaves-trough.

Two leaders, 6 inches in diameter, 14 feet 1 inch long, including elbow around water table. Four leaders, 4 inches diameter, 14 feet 1 inch long, including elbow around water table, and one receiver for each leader.

The roof, eaves-trough, leaders, roof-roll, cornice, and drip, are of the best No. 20 wire gauge galvanized sheet-iron, and painted on the outside with one coat of metallic paint.

Specifications and bill of iron for a corrugated galvanized-iron roof for a magazine building at the United States Powder Depot, New Jersey.

Quantity.	Articles.	Weight.
		Pounds.
13, 050 square feet	Galvanized. corrugated, best bloom, No. 20 wire gauge sheet-iron; depth of corrugations, ¾ inch; width of corrugations, 3¼ inches; size of sheets, 7 feet 8 inches by 3 feet, for roofing.	27, 110
816 feet	Galvanized sheet-iron stamped flashing, No. 20 wire gauge, 14 inches wide, 7 inches corrugated.	2, 150
204 feet	Ridge or roof roll, 3½ inches diameter, galvanized, sheet-iron of same quality and gauge as above-described roofing iron (to be made as per drawings).	394
118 feet	Cornice 5 inches by 5 inches best bloom, No. 20 wire gauge sheet-iron (to be made as per drawings).	258
408 feet	Drip, best bloom, No. 20 wire gauge sheet-iron (to be made as per drawings).	205
408 feet 2 inches	2-inch eaves-trough 13 inches by 4⅝ inches to 10⅞ inches, best bloom, No. 20 wire gauge sheet-iron (per drawings).	1, 605
26 feet	6-inch leader pipe, best bloom, No. 22 wire gauge sheet-iron (per drawings).	62
6	6-inch elbows, best bloom, No. 22 wire gauge sheet-iron	14
52 feet	4-inch leader pipe, best bloom, No. 22 wire gauge sheet-iron (per drawings).	91
12	4-inch elbows, best bloom, No. 22 wire gauge sheet-iron	22
2	Receivers for 6-inch leaders, No. 22 wire gauge sheet-iron (see drawings).	11
4	Receivers for 4-inch leaders, No. 22 wire gauge sheet-iron (see drawings).	13
432 feet 6 inches	¼-inch by 1½-inch bar iron, cut to required lengths	482
320	Bolts ⅜ inch by 1¼ inches, square head and nut	31
160	Bolts ¼ inch by 1¼ inches, countersunk heads	5
50	Bolts ¼ inch by 1 inch, countersunk heads	1½
1, 900	Bolts for strap and ridge roll, ¼ inch by ⅝ inch stove bolts	40
880	Galvanized U-shaped iron straps for purlins ⅛ inch by ⅝ inch by 14½ inches (see drawings).	369
28	Leader hooks (made as per drawings)	91
80	⅝-inch round bar iron tie rods, 3 feet long	206
27, 000	Iron rivets, tinned, 3/16 inch by ⅜ inch	162
27, 000	Burrs, tinned, for above rivets	65
160	Forged iron hooks for eaves-trough, ⅜ inch by 2 inches, as per following description (see drawings).	1, 184
		34, 572½

Hooks.	Depth of eaves-trough.	Total length.	Hooks.	Depth of eaves-trough.	Total length.
No.	*Inches.*	*Inches.*	*No.*	*Inches.*	*Inches.*
4	4 10/16	35	8	8 1/16	38 7/16
8	4 15/16	35 5/16	8	8 6/16	38 12/16
8	5 4/16	35 10/16	8	8 11/16	39 1/16
8	5 9/16	35 15/16	8	9	39 6/16
8	5 14/16	36 4/16	8	9 5/16	39 11/16
8	6 3/16	36 9/16	8	9 10/16	40
8	6 8/16	36 14/16	8	9 15/16	40 5/16
8	6 13/16	37 3/16	8	10 4/16	40 10/16
8	7 2/16	37 8/16	8	10 9/16	40 15/16
8	7 7/16	37 13/16	4	10 14/16	41 4/16
8	7 12/16	38 2/16			

All of the foregoing iron is to be equal to the best quality made by McCullough, of Philadelphia. It is to be of the shapes and dimensions shown in the drawings, and will be subject to inspection and test before acceptance.

The bidder to whom the contract is awarded will be furnished with the necessary drawings, a strict compliance with which in all their details will be required.

Record of tests of iron for Magazine No. 3, furnished by the Passaic Rolling Mill Company, of Paterson, N. J., under contract of September 22, 1884.

[Tested for Piccatinny Powder Depot by St. J. Clarke.]

Date.	Specimen.	Mark.	Size.	Area.	Broke at pounds.	Strain per square inch.	Limit of elasticity.
			Inches.	*Sq. inches.*		*Pounds.*	*Pounds.*
March 12	⅝" ●	·	0.63	.312	17,150	54,900	9,6
March 12	¾" ●	··	0.735	.424	23,650	55,700	11,7
March 12	⅞" ●	···	0.855	.574	29,900	52,100	15,6

Date.	Specimen.	Mark.	Limit of elasticity per square inch.	Elongation in 8 inches.	Elongation, per cent. of length.	Area of reduced section.	Per cent. of reduction.
			Pounds.			*Sq. inches.*	
March 12	⅝" ●	·	30,900	2.05	25⅝	.181	
March 12	¾" ●	··	27,600	2.15	26⅞	.219	
March 12	⅞" ●	···	26,800	1.8	22½	.292	

ESTIMATED COST OF BUILDING A RAILROAD FROM THE UNITED STATES POWDE DEPOT TO A JUNCTION ON THE MOUNT HOPE MINERAL RAILROAD, ABOU ONE MILE FROM PORT ORAM.

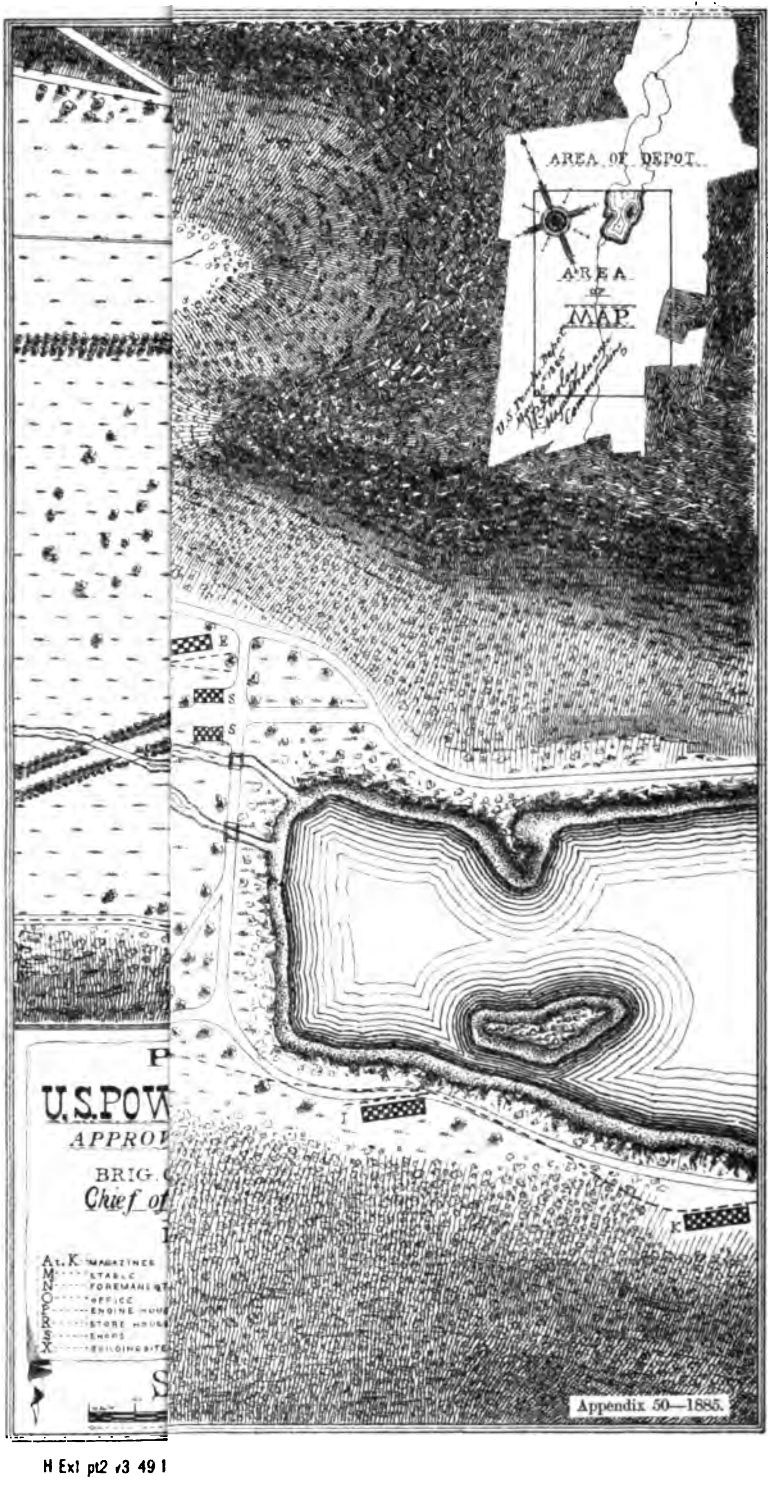
Clearing and grubbing 12,500 feet, at $5 per 100 feet	$625
3,100 cubic yards rock excavation, at $1.50 per yard	4,650
6,281 cubic yards earth excavation, at 30 cents per yard	1,884
19,055 cubic yards earth excavation, at 40 cents per yard	7,622
2,520 cubic yards earth excavation in ditches, at 50 cents per yard	1,260
450 cubic yards dry masonry in culverts, at $4 per yard	1,800
1,500 cubic yards dry masonry in side walls, at $1.50 per yard	2,250
410 cubic yards mortar masonry in bridges, at $6 per yard	2,460
1,920 cubic yards embankment, at 50 cents per yard	960
40 feet bridge superstructure, at $40 per foot	1,600
Ballast, broken stone 1 foot × 10 feet × 12,500=5,000 yards, at 75 cents per yard	3,750
Track superstructure, 12,500 feet, at $1 per foot	12,500
Right of way	3,000
Two sidings, 1,200 feet each, at $1.50 per foot	3,600
One water tank	500
One engine-house	1,500
Fencing, 2,900 feet, at 20 cents per foot	580
Engineering	1,800
Contingencies	1,879
Total	54,220

Line from Mount Hope Avenue to a junction on the Mount Hope Mineral Railroad at Mount Pleasant.

Station—	Distance from Station 1.	Angle.		Distance between stations.	To station—
	Feet.		° ′	*Feet.*	
1	0	Left..............	77 40	1, 514	2
2	1, 514	....do............	7 34	838	3
3	2, 352	....do............	23	848	4
4	3, 200	....do............	11 8	838	5
5	4, 038	Right	2 30	410	6
6	4, 448	....do............	4 50	102	7
7	4, 550	....do............	13 37	212	8
8	4, 762	....do............	11 5	2, 481	9
9	7, 243	... do............	12 43	950	10
10	8, 193	Left..............	18 24	1, 442	11
11	9, 635	Curve to left, 8°; radius, 716.		1, 250	12
12	10, 885	Tangent.		100	13
13	10, 985	Curve to right, 4°; radius, 1, 432.		700	14
14	11, 685	Tangent to Mount Hope Railroad.		970	15
15	12, 655	Angle, 54°.		....	Mt. Hope Railroad.

List of grades from Station 1 *on Mount Hope Avenue to junction on the Mount Hope Mineral Railroad at Mount Pleasant.*

Station—	Distance from Station 1.	Grade—	Grade per mile.	Grade per 100 feet.	Above or below base.
	Feet.		*Feet.*	*Feet.*	*Feet.*
1	0	....	....	....	+50. 6
1 to 2	700	Ascending.	53	1. 0	+57. 6
2 to 3	2, 400	Descending.	42	. 80	+44. 0
3 to 4	3, 000	Ascending.	16	. 30	+45. 8
4 to 5	4, 800	Descending.	16	. 30	+40. 4
5 to 6	5, 600	Ascending.	53	1. 0	+48. 4
6 to 7	6, 500	Descending.	37	. 70	+42. 1
7 to 8	7, 300	Ascending.	66	1. 25	+52. 1
8 to 9	8, 000	Do.	16	. 30	+54. 2
9 to 10	9, 000	Descending.	53	1. 0	+44. 2
10 to 11	9, 750	Do.	21	. 40	+41. 2
11 to 12	11, 450	Do.	158	3. 0	− 9. 8
12 to 13	12, 655	Do.	42	. 80	−17. 8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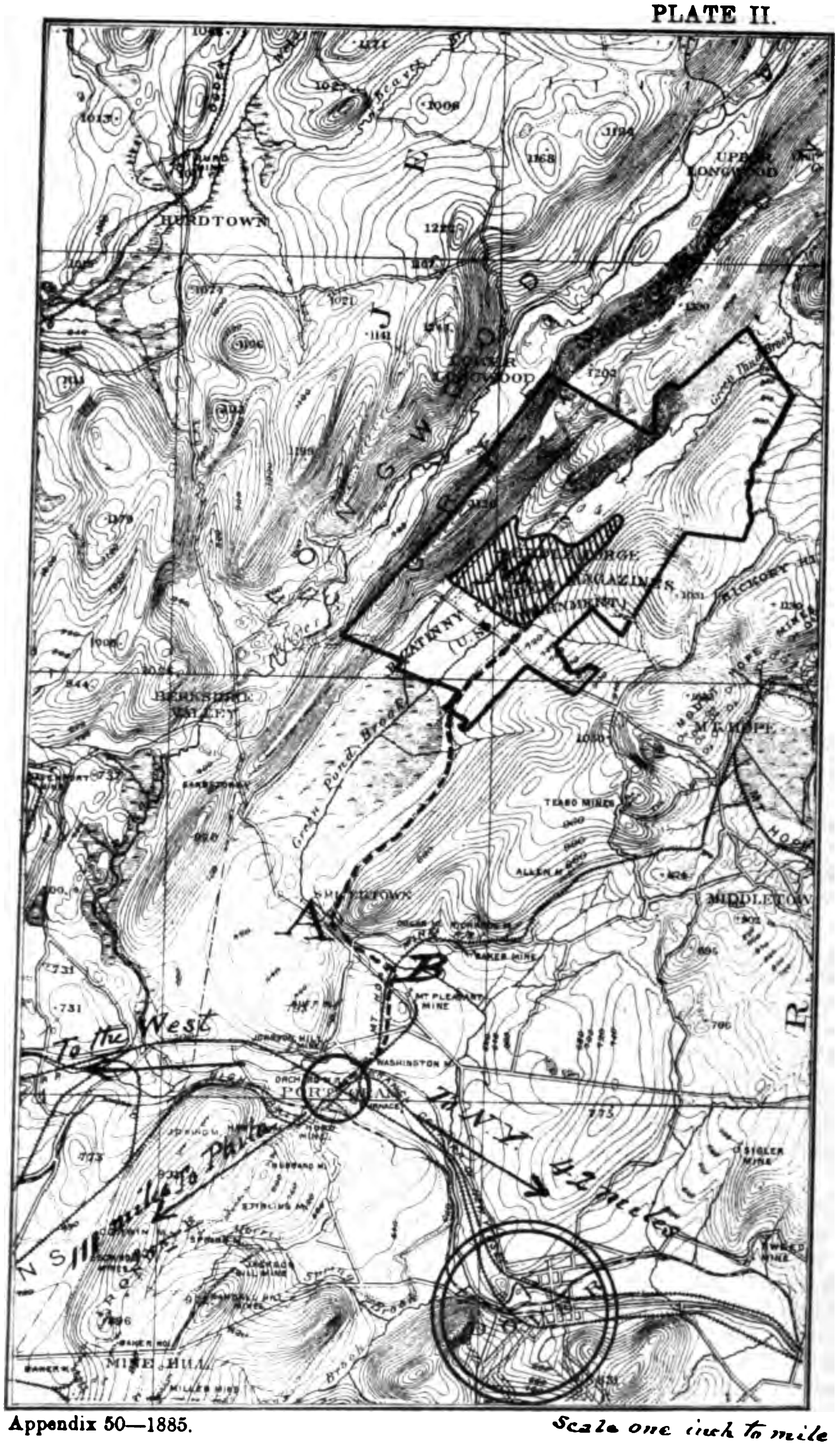
O OFFICE
P ENGINE HOUS
R STORE HOUS
S SHOPS
X BUILDING SITE
S
Appendix 50—1885.

PLATE II.



Appendix 50—1885.

Scale one inch to mile

H Exl pt2 v3 49 1

APPENDIX 51.

REPORT OF THE PRINCIPAL OPERATIONS AT THE ROCK ISLAND ARSENAL, ILLINOIS, DURING THE FISCAL YEAR ENDED JUNE 30, 1885.

BY LIEUT. COL. D. W. FLAGLER, ORDNANCE DEPARTMENT, COMMANDING.

(8 plates.)

SHOP H.—*An iron-finishing shop for the armory.*

(Plates I and II.)

This shop was commenced in August, 1878. The walls of the building had been completed before the beginning of the fiscal year. The work done on it during the year is as follows:

ROOF.

The roof has been put on and completed. This includes the iron truss roof frame (which has been described in previous reports); the wooden sheathing 1½ by 8 inches, planed and matched; heavy copper gutters, hips, valleys, peaks, and pediment flashings, and the slating. The total area of the roof is a little over 50,000 square feet, or about 1⅙ acres. This roof has the same skylight 4 feet wide along the whole of one side of the peak that was put on shops G and I, for the better lighting and ventilation of the third story. The glass used in the skylight is heavy ribbed cast plate, ⅜ inch thick, strong enough to bear a man standing on it, and to withstand the heaviest hailstones. A new and more secure method of fastening flashings to the pediment cornice stones, shown on Plate II, was adopted for this building. The old method was to fasten the top flashing (copper) into a small horizontal groove (in place of the groove *a*) by tamping in lead. This endangered splitting off the top of the stones, above the groove, and the groove could not be so securely packed as to always prevent water from getting around the flashing, and thence down the inside of the walls of the building. The new method is much more secure and is cheaper.

Down spouts.—From the roof gutters down to near the water table these down spouts are 5-inch diameter pipes, made of 2½-pound sheet copper brazed together. The remainder is a cast-iron pipe extending down into the sewers under ground. Ice in these down spouts, so common in cold climates, has caused much trouble in all the buildings previously erected. Snow melts in the sun on the roof. The snow water runs down in the spouts on the shaded sides of the buildings and freezes there until the spouts become filled with ice up to the gutters. The gutters then fill with ice, which backs the water up under the slating, and it runs down and freezes inside of the building. It is nearly impracticable to remove the ice before spring.

To overcome this difficulty I have adopted, after experimenting and successful trial, the new arrangement of the down spouts shown in Fig. 2 on Plate II, and have used this on Shop H. The water is allowed to fall from the bottom of the spout *a* one foot into the funnel below. It lessens somewhat the formation of ice in the spout below, and if the spout is filled the water then runs over the funnel and down the outside of the building, saves the gutters and slating, and prevents water from getting into the building. The ice has not yet in any case closed up the gap between the funnel and the spout above. Should it do so it can be seen and removed.

The fire-proof arches for all the floors have been put in and the floors laid. The first and second floors are of 1½ inch oak, matched and planed, and the third floor of 1¼-inch Southern hard pine, also matched and planed. The doors and windows have all been put in. The exterior area walls, steps, and platforms have been built and completed.

At the close of the year the plastering, painting, the basement floor and the grading, the stone walks, and the construction of the streets and avenues around the building were in progress.

SHOP K.—*A finishing and stocking shop for the armory.*

(Plate I.)

This shop was commenced in July, 1881. It is the last of the shops embraced in the plans for both the armory and the arsenal. The work done on it during the year is as follows:

STONE WORK.

The balance of the stone required for the second story (about one-fourth) has been purchased and cut, and the walls of this story have been completed. Nearly one-half of this story was built in the preceding year. About one-half of the stone for the third story has been purchased, and its cutting was in progress at the close of the year.

IRON WORK.

The iron floor beams for the third floor have been purchased and fitted for the building in the arsenal shops. The columns to support this floor, with their caps and bases, have also been cast and fitted in the arsenal shops. (The purchase of the floor beams consumed nearly one-half of the annual appropriation.)

STOREHOUSE A.

(Plate I.)

This building was commenced in April, 1883, and is the first of the storehouses required for the arsenal and armory. At the close of the preceding year the basement and first stories only had been built. The work done on the building during the year was as follows:

STONE WORK.

During the fiscal year the walls of the second and third stories have been built and the walls of the building completed. A portion of the area walls and the massive retaining walls for the wagon ramps leading to the basement have also been built.

ROOF.

The same roof as that for shop H, which has already been described in this report, has been put on this storehouse, except that the iron trusses, which in the shop roofs are placed 10 feet apart, are in the storehouse placed 16 feet apart, and they and the iron purlins are made more than correspondingly stronger. This gives a handsomer roof, and the arrangement permits a better disposition of the iron, so that although the roof is made about 11 per cent. stronger, its cost, at the same prices of labor and material, would be about 7¼ per cent. less.

During the year the iron columns for the second and third floors, and the floor timbers for these floors, were put in, and the third floor was completed. All of the windows and a portion of the doors were put in.

At the close of the year the laying of floors, plastering, painting, exterior granite platforms, steps, the walks, grading, streets, and special roads were in progress.

This building was partially described in my annual report for the year ending June 30, 1883, and a full description is deferred until after its final completion, which will be about November 1.

REPAIRS OF BUILDINGS, IMPROVEMENT OF GROUNDS, AND GENERAL CARE AND PRESERVATION.

(Plate III.)

In consequence of the totally insufficient appropriation under this head, it was absolutely necessary that nearly all of it should be expended in the care and preservation of buildings, the water-power, shores of the island, and the bridges. Much necessary work under this head had to be left undone, especially the repainting of buildings, for their preservation, and repairs of railroads, and no progress of importance could be made in the way of carrying on needful improvements of grounds, roads, &c.

The only considerable separate items of work done under this head are the following:

The construction of 830 feet of new sewer to discharge the sewage from the barracks and other buildings on East avenue into the river at a point below the pump-house. The excavation for this sewer had to be blasted through rock.

The construction of a strong gutter and sidewalk along the south side of Main avenue from West avenue to the west end of the island—nearly one mile. The work was done mainly by enlisted men, and was necessary, in connection with some ditching and draining, to complete the avenue and save its bank from washing.

The laying of a new 4-inch oak floor on the Rock Island wagon bridge. The old floor was entirely worn out and had become unsafe. The main floor beams of this bridge are wood, are decayed, and should be replaced by iron beams. The joists are also much decayed, and should be renewed.

The construction of a 10,000-gallon iron tank under the roof peak of shop C, with the necessary pumps, pipes, water-gates, and hose, for the better interior fire protection of this building and shop E (see Plate III transmitted herewith). The tank is filled from the water-main by a small pump, P, in the machine-shop. There are five 100-foot lengths of linen hose on each of the four floors, each supplied with the proper water-gate, so that in a few seconds a stream of water can be turned on to any part of each floor. This is the plan for the better interior fire protection of each shop, when in use, mentioned and partially described in my annual report of 1881.

It was hoped that, in consequence of efforts and representations made last year, a more suitable appropriation under this head would be made by Congress at its last session. I quote here some remarks made in my last annual report on this subject:

> I feel it my duty to invite the attention of the Chief of Ordnance to the fact that the appropriation allowed for this class of work for several years past has been much less than it ought to be. The utmost that is possible has been done to economize. It is nearly impossible that some improvement of grounds should not be carried on in connection with the construction of buildings, in order to utilize the material excavated, finish grounds around the buildings, and furnish needed improvements for use in carrying on other work Besides this, the buildings, roads, and other improvements are now of such magnitude that they require fully ten times as much for their proper care and preservation as they did thirteen years ago, at which time the appropriation for this work was double that which has been allowed in the past few years.
>
> I know of no better method of exhibiting this than by comparison. The extent of the work that ought to be done to keep in good order and repair streets, avenues, grounds, large bridges, shores of the island, railroads, gutters, walks, sewers, water-works, and the dams and gates and other constructions pertaining to the water-power is equal to the work of a similar kind done in a city of 10,000 inhabitants.
>
> In addition to this, the buildings and other constructions, taken care of by private owners in a city, must be kept in repair. I estimate that $9,000 ought to be expended in the coming year in repainting buildings and bridges alone, for their proper preservation.

WATER-POWER POOL.

(Plate IV.)

I regret to state that the small amount of work remaining unfinished in the water power pool, for which appropriation was made by Congress in the sundry civil act approved March 3, 1881, could not be completed last fall, in consequence of a sudden rise in the river.

The river had fallen to so low a stage ($2\frac{5}{10}$ feet) on August 25, 1881, as to make the work practicable, and the work of putting in coffer-dams was commenced on that date. The dams were completed, the pool drained, the necessary boats, derricks, pumps, tramways, and other appliances were put in order and in position, the necessary roads were completed, and the work of blasting and hauling out rock was commenced on September 7, and was continued until September 19, when the river rose suddenly about 4 feet, and a rise of 9 feet was reported to be coming down the river. The property was then secured, the dams cut, and the work abandoned. The highest stage ($11\frac{2}{10}$ feet) was reached on the 28th of September. The work is impracticable at a higher stage than 5 feet, and risk and increased cost commences at a stage of 4 feet.

About 4,000 cubic yards of rock were taken out between September 9 and 19, and sufficient experiments were made during the low water to demonstrate the practicability of washing out deposits in the pool through the water-ways constructed therefor in the Benham's Island Dam. No measurements of the amount washed out were made, but from observation of the effects on the bars I think not less than 10,000 cubic yards were washed out. I made and operated a cheap rough "digger" for digging up deposits where sufficient current for cutting away the bars could not be obtained. I am satisfied some machine of the kind will be required, and the experiments were carried far enough to demonstrate its economy and to furnish information for making plans for the machine. The device was made and tried, and is shown on Plate IV.

The wooden shaft A is supplied with hook-shaped steel teeth *a a a*, arranged on spiral lines. This shaft was revolved by a portable hoisting engine (on hand), placed on a mud scow (on hand). The timber arms B, hinged at *b*, and the tackle C, provided for raising and lowering the digger and keeping it at the required height against the edge of the bar. I had no means of moving the scow in the strong current except with poles and ropes. The experience gained showed that a small steamboat, to cost about $1,800, will be required for this purpose.

ORDNANCE AND ORDNANCE STORES.

In Appendix C (Plate V) is given a description and full detail report of the manufacture of silver marksman's pins and sharpshooter's badges. This work was commenced at this arsenal during the year.

Five thousand of the marksman's pins and two thousand of the sharpshooter's badges were manufactured.

In Appendix D (Plates VI, VII, VIII) is given a description and full detail report of the manufacture of steel skirmish targets, skirmish target cloths, and skirmish paper targets.

This work was commenced at the arsenal during the year.

Six thousand skirmish targets, nine thousand skirmish target cloths, and sixty-three thousand eight hundred and eighty-one skirmish paper targets were manufactured.

These reports are intended to give full detail information or instruction for the fabrication of these articles, and include bills of material and cost.

A similar description of the new rolling target and new Brinton target, prepared at this arsenal, was sent to the Chief of Ordnance October 9, 1884.

I invite attention to Capt. A. L. Varney's report (Appendix A) on the manufacture of the Elliott Intrenching Tool.

I would state, as a matter of interest, that 84,640 pounds of paper—three car-loads—have been consumed at this arsenal during the year in printing targets for the Army.

Respectfully submitted.

D. W. FLAGLER,
Lieutenant-Colonel of Ordnance, Commanding.

To the CHIEF OF ORDNANCE,
U. S. Army, Washington, D. C.
ROCK ISLAND ARSENAL, ILL., *October* 3, 1885.

APPENDIX A.

REPORT ON THE FABRICATION OF THE ELLIOTT INTRENCHING TOOLS.

ROCK ISLAND ARSENAL, ILL.,
February 14, 1885.

Lieut. Col. D. W. FLAGLER,
Ordnance Department, Commanding Rock Island Arsenal:

SIR: I have the honor to report the completion to-day of the Elliott Intrenching Tools made under my supervision in obedience to your fabrication orders Nos. 206 and 55, dated June 30, 1884, and December 2, 1884, respectively.

These tools, invented by First Lieutenant G. F. Elliott, United States Marine Corps, and patented by him September 25, 1883 (No. 285594) are of two kinds. One, adapted for use either as hoe or spade, is designated in the authority for their manufacture as an "Intrenching implement for infantry." The other, a combination hoe, shovel, pick, and crowbar, is simply called an "Intrenching implement."

The inventor designates the latter as "Spade A" and the former as "Spade B." The finished sample of "Spade A" and the wooden model of "Spade B," submitted as guide in manufacture, have been followed, except in the case of certain authorized deviations.

By your direction, tough second-growth hickory, steamed and bent, has been substituted for handles instead of the weak sawed ash of the sample. Certain other changes were made by authority of the Chief of Ordnance, at the request of Lieutenant Elliott. See indorsement by Chief of Ordnance of September 12 upon Lieutenant Elliott's application to be ordered to this arsenal. See also Lieutenant Elliott's letters (and inclosures) dated June 29, 1884, July 3, 1884, July 29, 1884, and (two) September 25, 1884, all of which are returned herewith.

Great pains have been taken to have the work done well and with the least practicable deviation from the models and the expressed wishes of the inventor. All the handles and spades of the B pattern have been made interchangeable, as also the pick handles, and spade blades of the A pattern.

The spade blades and handle straps of the B pattern have been browned by immersion in fuzed niter; a process introduced at Watervliet Arsenal in 1881, at the suggestion of Captain Clifford.

The handles of both A and B tools have been finished with oil and shellac. All metal parts of both tools, except the sheet steel used in the "A" pattern, have been forged from the best quality of tool steel. Owing to the nature of this material, and the necessity for accurate workmanship, these implements will be expensive under the most favorable circumstances. This small lot has been particularly so, owing to the lack of special tools and appliances, and the consequent necessity of employing hand labor upon much of the work that might otherwise have been more economically done by machinery. This is true both of the forging and the finishing.

COST.

IMPLEMENTS A.

Labor	[illegible]
Tools	[illegible]
General expenses	[illegible]

MATERIALS.

369 pounds tool steel, hard, at 10 cents per pound	[illegible]
84 pounds sheet steel, at 9 cents per pound	[illegible]
5 yards No. 12 iron chain, at 5 cents per yard	[illegible]

WOOD SHOP.

Labor on patterns	[illegible]
Labor on handles	[illegible]
100 feet hickory plank for handles	[illegible]
Total cost of 30 Implements "A"	[illegible]

Cost per piece, 22.48\frac{84}{100}$.

IMPLEMENTS B.

Labor	[illegible]
Tools	[illegible]
General expenses	[illegible]

MATERIALS.

87 pounds tool steel, hard, at 10 cents per pound	[illegible]
541 pounds tool steel, hard, at 11 cents per pound	[illegible]
25 pounds niter, at 10 cents per pound	[illegible]
4 emery wheels	[illegible]

WOOD SHOP.

Labor on patterns	[illegible]
Labor on handles	[illegible]
100 feet hickory plank for handles	[illegible]
Total cost of 30 implements "B"	[illegible]

Cost per piece, 19.64\frac{8}{30}$.

Of the material purchased for these tools and charged into the cost there remain on hand about 160 pounds tool steel in bars 1.675 by 3.75 inches; 50 pounds tool steel in bars 1.25 by 2.50 inches; 20 pounds sheet steel No. 16; 100 pounds scrap from all kinds of steel used.

The "transporting harness," or "skeleton leather bags," 30 of each (Figures ——, Plate I), were made of 6 to 8 ounce collar leather, and in conformity to the drawing and specification submitted with letter of September 19, 1884, referred to in the foregoing.

COST.

TRANSPORTING BAGS FOR IMPLEMENTS A.

	Labor	$56	32½
	General expenses	14	10
	MATERIALS.		
118	square feet collar leather, 7 to 8 ounce, at 18¼ cents per square foot	21	53½
6¼	ounces shoe thread, dark blue, at 98 cents per pound		40
3	balls black wax, at 50 cents per 100		2
30	brass end hooks, at 2$\frac{35}{100}$ cents each		70½
30	iron roller buckles, japanned, 1¼ inch, at 89 cents gross		18
30	iron roller buckles, japanned, 1 inch, at 71 cents gross		15
30	iron roller buckles, japanned, ⅝ inch, at 80 cents gross		17
1⅛	pounds brass rivets and burs, ⅝ inch, No. 12, at 23¾ cents per pound		28
5½	ounces escutcheon pins and burs, ⅝ inch, No. 13, at 30 cents per pound		10
	Total cost of 30 transporting bags for Implement A	93	96½

Cost per piece, $3.13.

TRANSPORTING BAGS FOR IMPLEMENTS B.

	Labor	$56	32½
	General expenses	14	10
	MATERIALS.		
97	square feet collar leather, 7 to 8 ounce, at 18¼ cents per square foot	17	70¼
⅜	pound shoe thread, dark blue, No. 3, at 98 cents per pound		37
3	balls black wax, at 56 cents per 100		2
30	brass end hooks, at 2$\frac{35}{100}$ cents each		70½
30	iron roller buckles, japanned, 1¼ inch, at 88 cents per gross		18
30	iron roller buckles, japanned, 1 inch, at 71 cents per gross		15
30	iron "sensible" buckles, japanned, ⅝ inch, at 80 cents per gross		17
1⅛	pounds brass rivets and burs, ⅝ inch, No. 12, at 23¾ cents per pound		28
5½	ounces escutcheon pins and burs, at 30 cents per pound		10
	Total cost of 30 transporting bags for Implement B	90	10¼

Cost per piece, $3.03.

With a considerable outlay in tools and machines the cost of the "A" pattern could probably be reduced in future manufactures to about $5 each, if ordered in large lots. The "B" pattern would cost about $4.

If modified in design, so as to permit less accurate workmanship and the use of less expensive material, the cost might be still further reduced.

Very respectfully, your obedient servant,

A. L. VARNEY,
Captain of Ordnance.

Respectfully submitted to the Chief of Ordnance, U. S. A., Washington, D. C.

D. W. FLAGLER,
Lt. Col. of Ordnance.

APPENDIX B.

ABSTRACT OF RECORD KEPT AT THE ROCK ISLAND BRIDGE DURING THE

PASSING NORTH.

Engines with trains	[illegible]
Engines without trains	[illegible]
Total engines	[illegible]
Passenger cars	[illegible]
Freight cars	[illegible]
Foot passengers	[illegible]
Teams	[illegible]
Steamboats, up	[illegible]
Barges, up	[illegible]

PASSING SOUTH.

Engines with trains	[illegible]
Engines without trains	[illegible]
Total engines	[illegible]
Passenger cars	[illegible]
Freight cars	[illegible]
Foot passengers	[illegible]
Teams	[illegible]
Steamboats, down	[illegible]
Barges, down	[illegible]
Rafts, down	[illegible]

D. W. FLAGLER,
Lt. Col. of Ordnance, [illegible]

APPENDIX C.

REPORT ON THE FABRICATION OF MARKSMAN'S PINS AND [illegible] *BADGES (SILVER) AT ROCK ISLAND ARSENAL.*

(Plate V.)

ROCK ISLAND ARSENAL, ILLINOIS,
September 1, [illegible]

To the CHIEF OF ORDNANCE,
U. S. Army, Washington, D. C.:

GENERAL: In March, 1884, I received instructions from the Chief of [illegible] get up and submit to him designs for a marksman's pin and a sharpshooter's [illegible] Pencil sketches were inclosed to indicate what was required. Many [illegible] made and submitted, and finally, in May, 1884, models were approved and [illegible] The cross was somewhat similar to the pendant of the present model of the [illegible] shooter's badge, and the pin was somewhat similar to the present model of the [illegible] man's pin. Both were provided with brooch pins for attachment to the [illegible] coat.

Two thousand five hundred of the marksman's pins and 1,000 of the [illegible] manufactured and issued to the Army. These were cast from statuary [illegible] finished on the polishing wheel, with a file and emery paper, and burnished.

In the fall of 1884 I was informed by the Chief of Ordnance that [illegible] were not satisfactory, and requested to submit handsomer designs. It was [illegible] that if the expense would not be too great they might be made of silver. [illegible] signs were made and submitted, until finally the present models were [illegible] adopted. These are now so well known that they need little description. [illegible] made of sterling silver. The pin is similar to the old one, except that the [illegible] altered, the scroll work removed, and the representations of [illegible] were [illegible]

ge a brooch, bearing the word "Sharpshooter," was adopted for attach-
wearer, and to this a cross somewhat similar to the old one is hung as a

FABRICATION.

rk is new, and no workmen acquainted with it were available, many ex-
ıd much tedious labor and study were required to bring it to perfection.
ıdebted for assistance to Mr. J. Drayton, master machinist, Mr. H. Shunk,
achine shop, and Mr. R. C. Munson, foreman of metallic equipment work.
osed that the engraved pieces could be stamped out with dies in same
coin is stamped. But it was found that a suitable press, dies, and tools
od could not be produced for less than about $4,000, and this method had
oned.
d finally adopted is that of placing the silver on a die and passing both
er between rolls. This method is employed in the manufacture of jew-
only irregular ornamentation is required, and for such work it presents
lty. But our work consisted of regular forms, letters, and lines. The
iation from the required form could be readily detected by the eye. In
netal is pressed up against the die forms on one side and drawn away
n the other. Allowance had to be made for this in cutting the dies, and
g in regard to the work was new, it involved many delays and tedious

re of dies.—I believe a *female* die of the required form cannot be cut. The
loyed was as follows: A *male* die of the required form was first cut. This
ık in another piece of steel, to make the female die. The latter was first
ıealed, and a pit one-sixteenth inch deep was cut in the surface of the
he female die was to be sunk. This pit had the same outline as the male
to keep the male die from slipping when struck. The male die was then
t, and struck five or six careful blows by hand with a heavy sledge ham-
eel had then to be reannealed, and the process repeated from four to seven
a perfect die was obtained. The surface of the steel in which the female
sunk was then planed down till the depth of the *pit* was planed off, and
he required depth of die was left.
g the male die it is sunk unevenly; one edge or end is driven down more
r. This must be corrected in planing off, so as to leave an even depth of
ıroughout. The best method of doing this is to make a gauge. First
of soft metal (lead and antimony answer well) in the female die. Then
ınd dress down its back till the exact level required for the face of the
obtained. Then put it back and dress down the face of the female die

e die was then tempered, its face ground and polished, and was ready for
ove method is probably the only practicable one for making these dies.
ed me to make several dies from one costly cut die.
A piece of silver of the required dimensions was then placed on the die, and
silver passed between the rolls (Plate V). The *die rolls* were devised and
arsenal. They are shown on Plate V. The rolls R R are made of tool
tempered, and then carefully and accurately ground and polished. They
rge journals and such hardness and stiffness as to prevent any percepti-
ion or spring during the rolling. The compresses C C permit the setting
o the required fine gauge.
ing is a brief description of all the operations of manufacture, with bills
, cost, and cost of labor:
silver is received at the arsensal subject to the following rules of inspec-
eets to be rolled to an even thickness to fifty-eight thousandths of an inch;
t to be cut straight and parallel. Size of sheet best suited for use 24 inches
ches wide. Silver must assay 92½ per cent. fine. (Assays of silver have
nade for me by the superintendent of the United States mint at Philadel-

lver wire for making the three rings by which the pendant cross is hung
shooter pin (or broach), and the sterling-silver pin-tongue hinges and
oth pins, are purchased, assayed, and inspected in the same manner. The
ınd wire for making the pin-tongue rivets, are of German silver, that they
e necessary strength and hardness.
ection the silver is stored in the office safe and issued in lots daily as re-

tion.—The sheets are cut into strips 2$\frac{3}{16}$ inches wide for marksman's pins,
ide for sharpshooter's badge pins, and in pieces 1¼ inch by 1¼ inch for the
s.
ation.—Stamping the engraved surfaces of pins and cross: This is done
een the die rolls (Plate V). The operator places the strip or piece of sil-

ver on the die and passes both silver and die between the rolls. In rolling the pin the strip of silver is rolled or drawn out about one-eighth of its original length. The stamped piece is partly cut off by the die in rolling, and is then broken off with a pair of pincers. The end is then trimmed to shape for the next piece with a spring cutter. One operator stamps 725 pieces in eight hours.

Third operation.—The stamped pieces come from the rolls slightly curved. They are straightened by placing the face of the stamped silver on a smooth plate of steel and passing both between the same rolls.

Fourth and fifth operations.—Milling and trimming the ends and sides: One pin is clamped in an iron die which was stamped from the same male die that made the female die in which the silver piece was stamped. This iron die is then placed in a milling machine, and the ends of the silver piece are milled to shape with one cut. The iron die is for adjusting the silver piece in the mill with reference to its engraved face. Twelve pieces are then placed in a holder which fits the milled ends, and the sides of the whole twelve pieces are milled off at once. The crosses are not milled. They are trimmed off with blank punch and die in a press, the face of the punch being sunk to receive the engraved face of the cross and center it.

Sixth operation.—Polishing: The pins and crosses are placed in wooden holders, and faces and edges ground on an emery wheel provided with a tin hood to catch the silver dust.

Seventh operation.—Making the silver rings for hanging the cross of the badge. Enough silver wire is wound on a mandrel to make about 100 rings, and then cut with a fine saw on a milling machine.

Eighth operation.—Brazing on joints and catches: The silver solder is cut into pieces about one sixty-fourth inch square. The joint or catch is placed on the back of the pin and held in place by spring plyers which locate the joint or catch. A piece of solder is put on, moistened with borax water for a flux, and the brazing completed in a blowpipe flame. The melting point of suitable silver solder is not much below that of the silver, and great care is required to avoid melting the silver. The pieces are held to the flame with long spring-steel plyers or on a sheet of asbestos. The silver rings for hanging the cross to the badge pin are brazed in the same manner as above.

Ninth operation.—Filing and polishing: The pins and cross are filed on the face and edge and then polished with a pine stick covered with French emery paper.

Tenth operation.—Dipping: The silver pieces are buried in white sand in a sheet-iron pan; heated to a dull red color over a gas flame; then quickly removed and dipped in a sulphuric acid and water bath, temperature 200° F. (acid 1, water 9); and then thoroughly washed with a brush in castile-soap water, and dried in hot, dry, hard-wood sawdust. If this operation is successful, the silver, when brushed off, will be snow white.

Eleventh operation.—Riveting in pin tongues: The pin tongue is placed in the joint, a piece of rivet wire is forced into place with a special pincers devised for the purpose, and then both ends are riveted down with special pincers devised for the purpose. The catch is then opened and the pin tongue set to give the required spring.

Twelfth operation.—Burnishing: The pins and cross are placed in a wooden holder, face upwards, covered with castile soap suds, and all the parts in relief are burnished with a flat steel burnisher, the latter being kept bright by frequent polishing on leather rubbed over with oxide of tin.

In all the operations, pieces of silver are counted and weighed out to the operatives, and the pieces returned are counted, and pieces and scrap and millings and filings returned are all weighed, to ascertain if there has been any loss. The total loss is about one eleven-hundredth part of the weight. The scrap, millings, and filings are returned to the contractor, to be reconverted into sheet silver.

Packing.—The pins and crosses are packed, each one separately, in pink wool, in a suitable pasteboard box properly labeled, and these boxes are then packed in large pasteboard boxes for shipment, fifty marksman pins in one box and twenty-five badges in one box.

Bill of materials for and cost of 100 *sharpshooter's badges.*

29.46 ounces sheet silver, at $1.07	[illegible]
0.067 ounce loss, at $1.07	[illegible]
1.43 ounces silver wire, at $1.20	[illegible]
0.12 ounce silver solder, at $0.95	[illegible]
0.20 ounce German silver wire, at $0.04	[illegible]
104 pin tongues, silvered, 1½″	[illegible]
104 silver joints, $\frac{3}{16}$″	[illegible]
104 No. 1 silver ring catches	[illegible]
Reworking and converting into sheet 40.36 ounces of scrap, millings, and filings, at $0.07	[illegible]
0.16 pound pink cotton, at $0.75	[illegible]
100 labels, small	[illegible]

4 labels, large	$0 02
100 packing-boxes, small	1 21
4 packing-boxes, large	24
Alcohol, acid, soap, &c	26
Tools	80
Labor manufacturing	15 99
General expenses	3 20
Total	61 08

Cost per badge, $61\frac{1}{10}$ cents.
Piece price recommended, 75 cents.

Bill of materials for and cost of 100 marksman's pins.

21.4 ounces sheet silver, at $1.07	$22 90
0.3 ounce silver lost, at $1.07	03
105 German silver pin tongues (silvered), 2"	37
105 No. 2 silver ring catches	1 86
105 ½-inch silver joints	1 50
0.1 ounce silver solder, at $0.95	09½
0.24 ounce German silver rivet wire	02
Reworking and converting into sheet silver 9 ounces scrap, millings, and filings, at $0.07	63
Alcohol, acid, soap, &c	08
0.1 pink cotton	08
100 packing-boxes, small	1 11
2 packing-boxes, large	12
100 labels, small	07
2 labels, large	01
Labor manufacturing and packing	8 01
General expenses	1 60
Tools	40
Total	38 88½

Cost per pin, 39 cents.
Piece price recommended, 50 cents.

The tools and appointments on hand are sufficient for the manufacture of 300 sharpshooter badges per day, 500 marksman pins per day.

Respectfully submitted.

D. W. FLAGLER,
Lieutenant-Colonel of Ordnance, Commanding.

APPENDIX D.

REPORT ON THE FABRICATION OF SKIRMISH TARGETS, TARGET CLOTHS, AND SKIRMISH PAPER TARGETS, D, E, AND F.

ROCK ISLAND ARSENAL, ILLINOIS,
September 21, 1885.

To the CHIEF OF ORDNANCE,
U. S. Army, Washington, D. C.:

GENERAL: On March 29 and June 26, 1885, I received instructions from the Chief of Ordnance to manufacture 6,000 metal skirmish targets of the forms shown on Plate XVII, of Captain Blunt's "Rifle and Carbine Firing." It was thought that the frames should be made of iron bar, and that possibly bar of wedge-shaped *cross*-section could be used advantageously.

Cotton cloths of the same shapes as the metal frames were required for covering the frames, and it was required that some suitable method should be devised for attaching these cloths to the frames; also, black paper targets or silhouettes were required of the same shape as the frames, to be pasted to the target cloths.

Many experiments were made to determine the best metal and form of same for the target frames. These finally determined the adoption of steel bar of the cross-section shown in Fig. 2, Plate VI. The following extract is taken from my partial report of May 4, 1885. The experimental firings were made by Captains Butler and Varney, Ordnance Department.

"I inclose herewith a drawing showing the effect of experimental firing to de
mine the dimensions, shape, and metal required for the frames.

"The results of the firing seemed to show, first, that iron of no form or reason
weight will answer. Bullets striking a sharp edge of iron dented and injured the
as much or more than those striking a square edge (see drawing).

"Second. The elastic limit against bending of iron being low, the iron bars w
bent badly in the direction of the bullet's flight.

Third. The steel bar suffered none of the above bad effects. A bullet striking fa
on a sharp edge was split, without marring the steel. The elasticity of the steel
vents its bending. I think the sharp or wedge-shape edge for the steel desirabl
all respects. It so disposes the metal as to increase the beam strength. It red
the liability of hits, and if hit fairly on the edge splits the bullet. If hit on the s
of the edge, the spring or elasticity of the steel prevents the bar from being per
nently bent laterally.

"The cross-section finally adopted is shown on the drawing (Fig. 2, Plate VI).

(Plate VII, Figs. 1 and 2.)

The brace.—The brace adopted is made of the same steel and of the same cros
tion of bar, because it is as liable to receive *hits* as the frame. The lower e
hooked, to prevent the target from being blown down by a rear wind. The u
end hooks into a hole punched in the frame. The brace can revolve around
point in a plane perpendicular to the target. When the target has been stood u
the desired angle with the horizon, the lower end of the brace can then be pa
(with the foot) or driven into the ground, without altering the position of the ta

FABRICATION OF THE TARGET FRAMES.

The steel bar weighs 1.1 pounds per foot. Special rolls were required for its ma
facture, and it cost, delivered at the arsenal, 2¼ cents per pound. It was purcha
in suitable lengths, avoiding waste, and was then cut up into pieces of requi
lengths (see Plate VII).

BILLS OF STEEL (PLATE VII).

Skirmish target D.

1 bar steel 18'.0 long:	
Piece A	7' 10"
Piece C	5' 4"
Brace	4' 10"
½ bar steel 18' 6" long:	
Piece *b*	6' 3¼"
Piece *d*	1' 5½"
Piece E	1' 6"
Total	27' 3" = 30 poun

Skirmish target E.

1 bar steel 14' 9" long:	
Piece A	5' 2"
Piece *b*	5' 3"
Piece *c*	2' 4"
Piece *d*	2' 0"
½ bar steel 14' 0" long:	
Brace	4' 8"
Total	19' 5" = 21.4 poun

Skirmish target F.

½ bar steel 15' 6" long:	
Piece A	5' 5"
Piece *b*	2' 4"
Total	7' 9" = 8.5 poun

Punching.—The method adopted for fastening on the target cloths (to be descri
further on) is to tie them on with strings. This required that a hole shoul
punched in the steel bar for each string. These holes are marked *h* on Plate V

It was desirable that they should not be larger than one-quarter inch diameter, lest they might weaken the frame. Steel of the required hardness and elasticity made the punching of so small a hole very difficult. Drilling so hard a steel would have been difficult also and too expensive. After many trials of English and American tool steels, an open-hearth steel was obtained from Canton, Ohio, that would do the work without breaking. The rivet holes were also punched. These are seven-sixteenth inch diameter, and their punching presents no difficulty.

Shaping the bars.—This was done on a special *shaping* or *bending machine* manufactured for the purpose at the arsenal.

This machine is shown on Plate VIII.

Dies (Figs. 2 and 3) for two shapes are shown on the drawing, and the method of bending is sufficiently illustrated. Care is required in designing the dies to prevent the bar from being drawn endwise from its proper position when the dies come together. A steel lever thrust into a hole below at the point (*b*), and pulled up against the steel bar by hand above, was used to hold the steel and prevent its slipping. In some cases two of these, at different points, were used.

The steel was shaped hot. A long special furnace for the heating was conveniently placed between the punching and bending machines, and, after punching, the bars were put into one end of the furnace and pulled out at the other for bending.

Forging.—The wedge-shaped edges of the steel, where riveted together, if not altered, would give the joint drawn in Fig. 5, Plate VII. A bullet striking on this point would strain the frame unduly and tend to draw or break the rivet. To prevent this, and give a sharp edge at the joint also, the form of the bar was altered while hot, under a drop so as to make the joint as shown in Fig. 6. This was done before riveting. The sharp points of the frame which enter the ground—the round at one end of the brace and the sharp point at the other—were forged under a helve power hammer. The crook in the brace, where it enters the ground, was then formed on the bending machine.

Coal-tarring and crating.—The frames when finished were first heated in the foundry core-oven, then dipped in a vat of hot coal tar, and when dry were sent to the packing-house and crated for shipment.

Convenient numbers to crate in one package are 8 targets D, 8 targets E, and 16 targets F.

TARGET CLOTHS.

The method finally devised and adopted for attaching the target cloths to the metal frames was to tie them on with strings. I think it is sufficiently expeditious; it can-never give trouble; the attachment cannot be seriously damaged by firing, can be readily repaired by a soldier if damaged, and it gives an easy means of stretching the cloth to any desired tautness.

Had the frames been in the form of a parallelogram, or of any form having straight borders, the cloth could have been attached by tying the strings around the frame. As the edges of the frames are curves, it is necessary to so attach the strings at the outer part of curves that they cannot slip. This is effected by punching holes in the frame, as has been mentioned. Corresponding holes are made near the edge of the cloth. The holes in the cloth are reinforced with leather washers five-eighth inch diameter, and a brass eyelet is put through both leather and cloth and riveted down. The number of holes in the cloth and in the target frame of each target is as follows: Target D, 36; target E, 24; target F, 15. The top of the cloth is marked "top." If the soldier commences tying at the *top* and passes from there around the edges, he will find the holes to coincide, and can have no trouble in getting the cloth on the frame correctly. The strings are to be put through the holes in the frame first, and then knotted at the near edge of the frame. The holes in the cloth are so spaced that they will come just opposite the front edge of the frame without stretching. One end of the string is then passed through the eyelet hole in the cloth and the cloth drawn around the outside of the frame and tied. The cloth can be stretched the whole width of the steel bar of the frame, 1¼ inches, or any less amount that is desired.

Fabrication.—The cotton, 72 inches wide, is mounted in twelve rolls at one end of a table. Twelve pieces are drawn out on the table at one time; the top piece is marked with a templet for the cutting and punching, and then the whole twelve pieces are cut at once with a long knife, and all are punched at once with an ordinary punch. One man cuts and punches 300 D cloths, 400 E cloths, and 500 F cloths in eight hours. The leather reinforce washers are punched out on an ordinary punching machine. The eyelets are put in by boys with special hand machines devised for the purpose. In making the strings, the string is first wound on spools. The spools are made of four tin plates set at right angles, the distance between the outer edges of the tin being the length of a string. These edges are then dipped in gum shellacand allowed to dry. The strings are then cut along the edges of the tin. The gum forms a stiff tag to facilitate passing the string ends through the holes in the target cloths and frames. The strings are tied up in hanks and properly labeled, 36 strings in a hank for the D target, 24 for the E, and 15 for the F. In issuing, 5 hanks or sets of strings were issued for every 4 targets.

PAPER TARGETS.

As has been stated, these are black paper silhouettes having the same contour as the target frames and cloths. It was found that pure black paper could not be obtained, except with a glossy surface, which reflected the light and defeated the object sought. After much trouble a dead blue-black (nearly black) paper was obtained which showed well in the sun at a distance, and was approved by the Chief of Ordnance. The paper weighs about 2 pounds per 100 square feet. It is purchased in sheets—for the D target 27 by 68 inches, for the E 27 by 42 inches, for the F 27 by [illegible] inches. By making a crooked cut across the latter size two F targets are obtained from one sheet.

The silhouettes are cut out of the paper as follows:

About one-half a ream of paper is placed between two stiff wood templets having the same contour as the silhouette to be cut. The paper is then compressed with heavy iron clamp screws, and the silhouettes are sawed out with a large band scroll-saw. The clamp screws are removed from in front of the saw and placed behind it from time to time as they are reached. One man can cut out 2,000 D's, 2,500 E's, and 3,000 F's per day.

Bill of materials for and cost of one skirmish target D (steel frame).

Thirty pounds steel bar, at 2½ cents per pound	$0 75
Eight ⅝ by 1 inch round-head rivets	[illegible]
Coal	[illegible]
Labor	[illegible]
Coal-tarring	[illegible]
General expenses	[illegible]
Patterns, dies, and tools	[illegible]
	1 17

In future manufactures deduct 6 cents for patterns, dies, and tools on hand. The above does not include cost of crating for shipment, which was about 11 cents each.

Bill of materials for and cost of one skirmish target E (steel frame).

Twenty-one and four-tenths pounds steel bar, at 2½ cents per pound	$0 [illegible]
Five ⅝ by 1 inch round-head rivets	[illegible]
Coal	[illegible]
Labor	[illegible]
Coal-tarring	[illegible]
General expenses	[illegible]
Patterns, dies, and tools	[illegible]
	[illegible]

In future manufactures deduct 4 cents for patterns, dies, and tools on hand. The above does not include cost of crating for shipment, which was about 9 cents each.

Bill of materials for and cost of one skirmish target F (steel frame).

Eight and one-half pounds steel bar, at 2½ cents per pound	[illegible]
Two ⅝ by 1 inch round-head rivets	[illegible]
Coal	[illegible]
Labor	[illegible]
Coal-tarring	[illegible]
General expenses	[illegible]
Patterns, dies, and tools	[illegible]
	[illegible]

The above does not include cost of crating for shipment, which was about 4 cents each.

The foregoing statement of cost of patterns, dies, and tools, does not include the bending machine (about $450) and the furnace (about $145), which were charged to the arsenal plant.

Bill of materials for and cost of 100 D target cloths.

MATERIALS.		
52 yards cotton cloth, 72 inches wide, at 20 cents per yard		$10 40
3,625 brass eyelets, at 75 cents per thousand		2 72
Miscellaneous articles		25
LABOR.		
Cutting and punching	$0 70	
Making leather reinforces	36	
Splicing on arm	60	
Putting in eyelets	2 00	
		3 66
Special tools		10
General expenses		75
Total		17 88

18 cents each.

Bill of materials for and cost of 100 E target cloths.

MATERIALS.		
44 yards cotton cloth, 72 inches wide, at 20 cents per yard		$8 80
2,425 brass eyelets C, at 75 cents per thousand		1 83
Miscellaneous articles		20
LABOR.		
Cutting and punching	$0 55	
Making reinforces	24	
Putting in eyelets	1 35	
		2 14
Tools		07
General expenses		43
Total		13 47

13½ cents each.

Bill of materials for and cost of 100 F target cloths.

MATERIALS.		
24 yards cotton cloth, 72 inches wide, at 20 cents per yard		$4 80
1,525 brass eyelets, at 75 cents per thousand		1 15
Miscellaneous articles		15
LABOR.		
Cutting and punching	$0 40	
Making reinforces	15	
Putting in eyelets	80	
		1 35
Tools		5
General expenses		27
Total		7 77

8 cents each.

Bill of materials and cost of 100 paper skirmishing targets.

D.

23.5 pounds paper, at 8½ cents per pound	$2 00
Labor and general expenses	25¼

Cost per target, 2¼ cents.

E.

13.4 pounds paper, at 8½ cents per pound	$1 14
Labor and general expenses	22

Cost per target, 1⅜ cents.

F.

6 pounds paper, at 8½ cents per pound	$0 51
Labor and general expenses	18¼

Cost per target, $\frac{7}{10}$ cents.

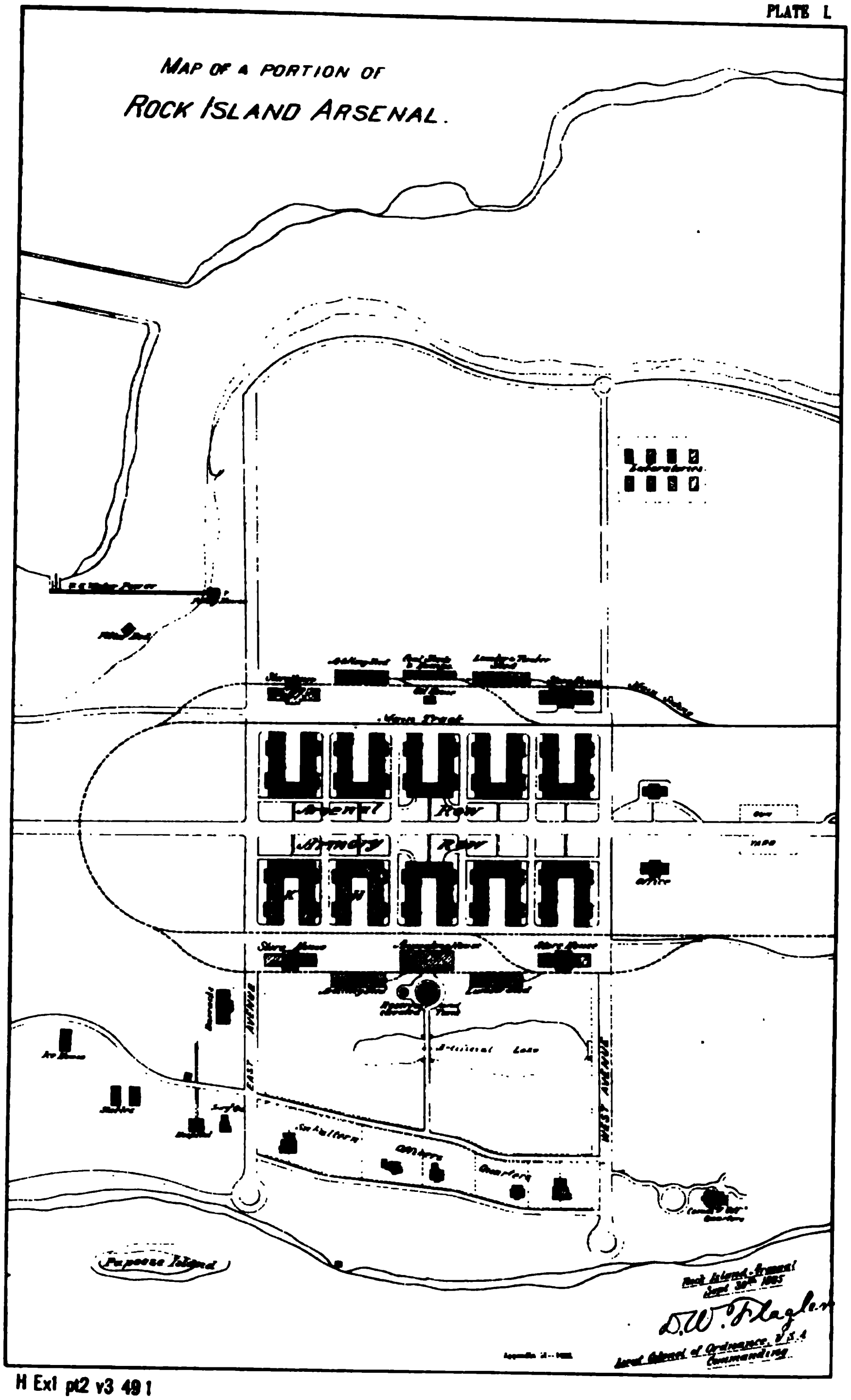
The capacity of tools now on hand is sufficient for making per day: 95 D, 125 E, 250 F, targets; 250 D, 350 E, 550 F, target cloths; 2,000 D, 2,500 E, 3,000 F, paper targets.

Respectfully submitted.

D. W. FLAGLER,
Lieutenant-Colonel of Ordnance, Commanding.

PLATE L

MAP OF A PORTION OF ROCK ISLAND ARSENAL.



Rock Island Arsenal
Sept 30th 1885

D.W. Flagler
Lieut Colonel of Ordnance, U.S.A.
Commanding

H Ex1 pt2 v3 49 1

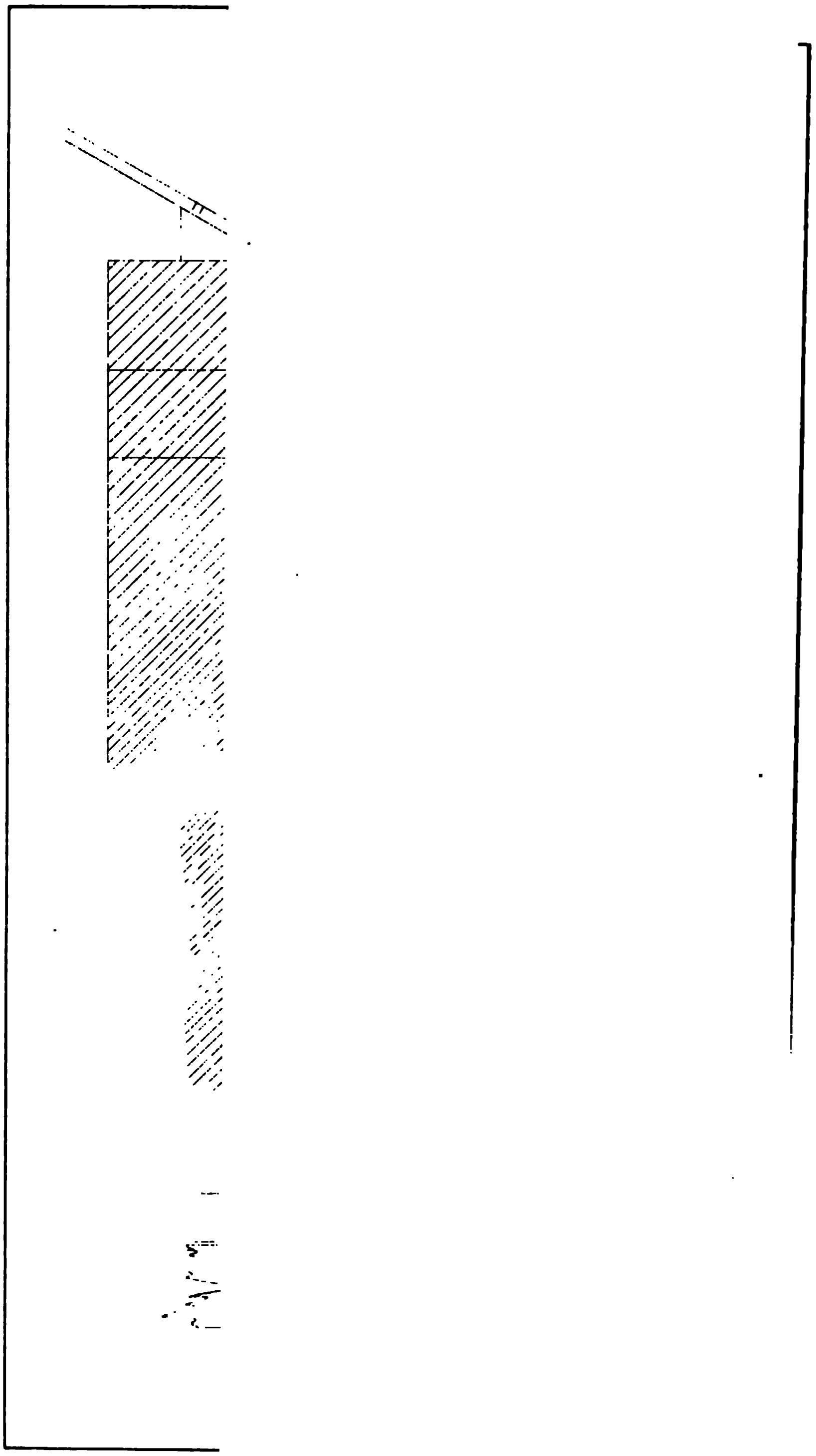
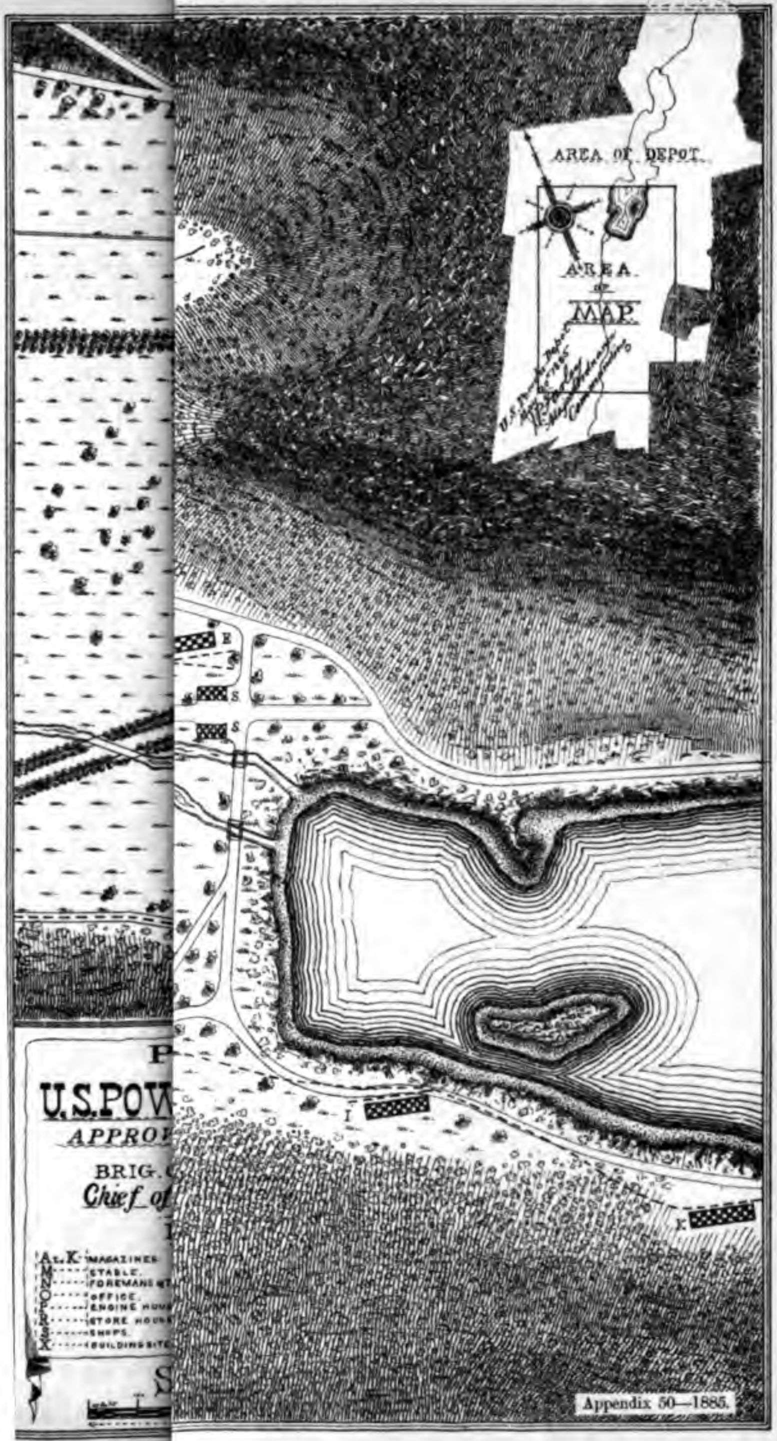


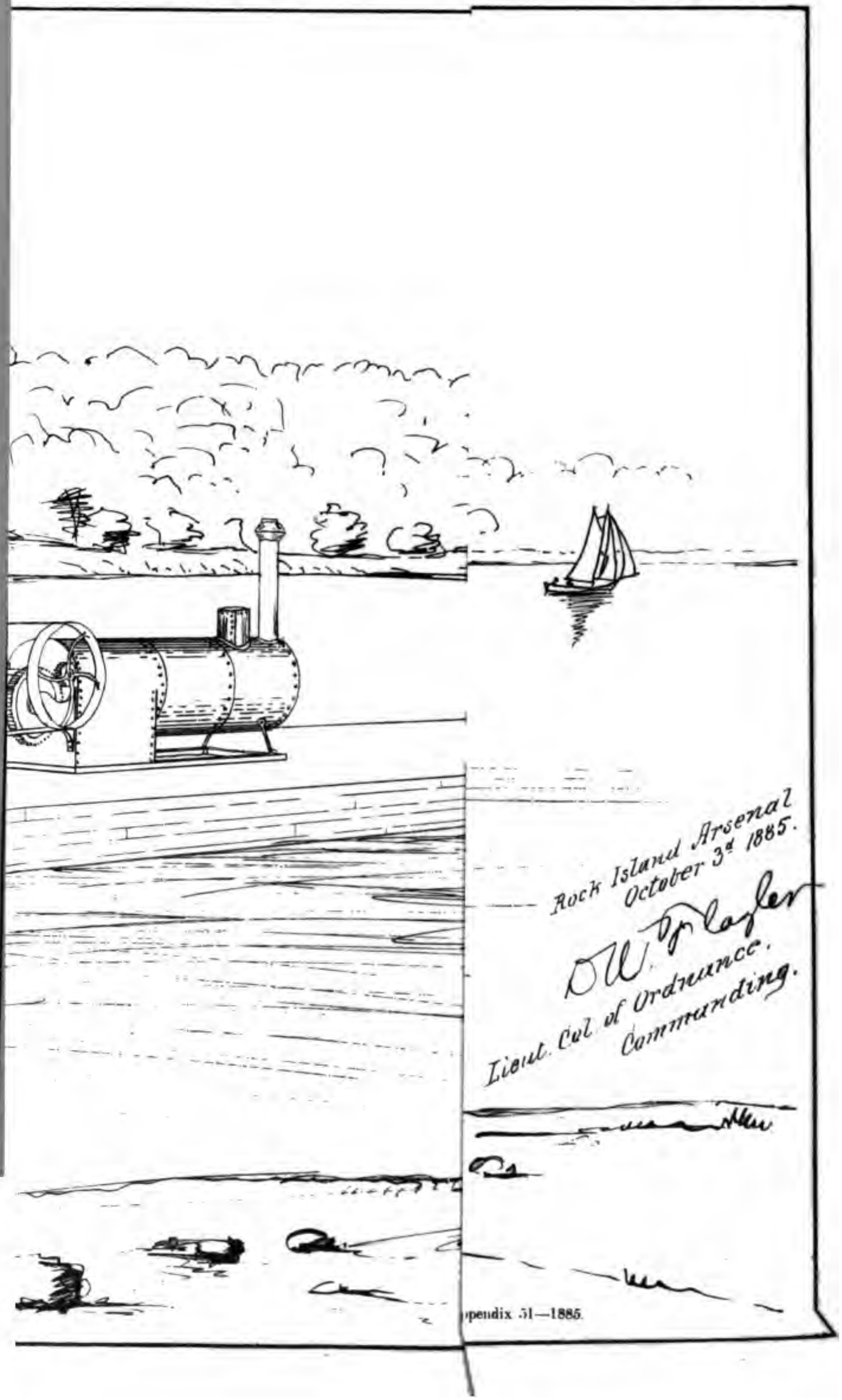
PLATE I.



Appendix 50—1885.

H Ext pt2 v3 49 1

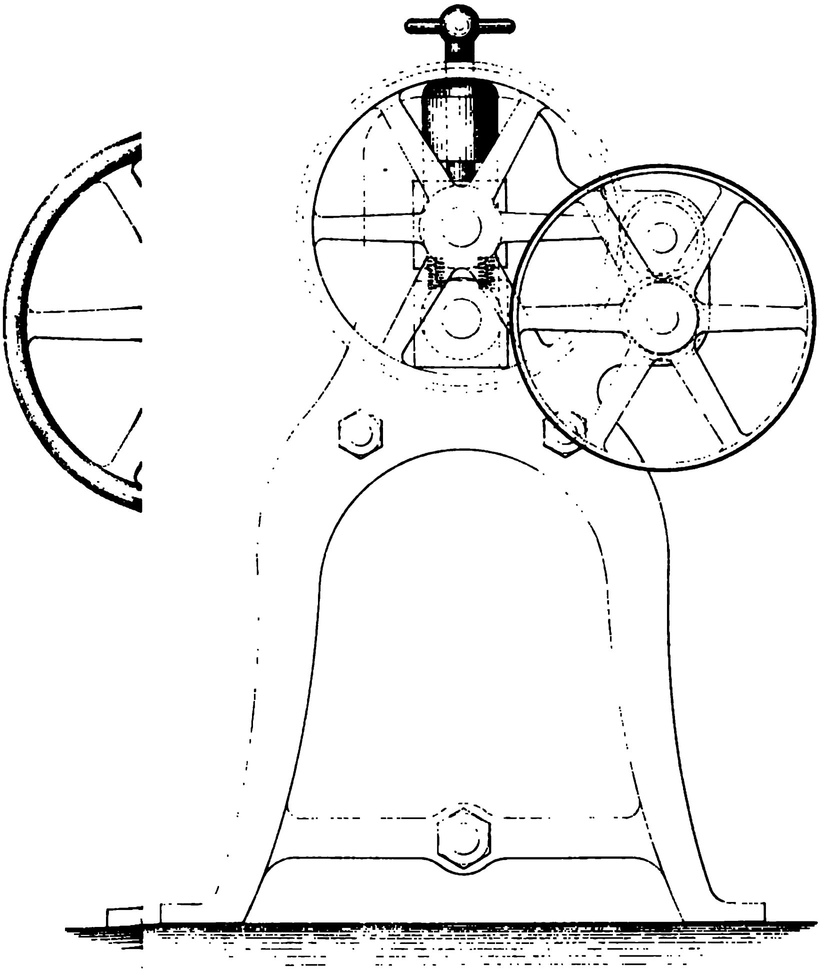
PLATE IV.



Rock Island Arsenal
October 3d 1885.
D.W. Flagler
Lieut. Col. of Ordnance,
Commanding.

ppendix 51—1885.

PLATE V.



2 Feet

Rock Island Arsenal
September 29th 1885.

D W Flagler
Lieut. Colonel of Ordnance, U.S.A
Commanding

Appendix 51—1885.

E.

13.4 pounds paper, at $8\frac{1}{4}$ cents per pound..

Labor and general expenses ....

Cost per target, $1\frac{3}{8}$ cents.

F.

6 pounds paper, at $8\frac{1}{4}$ cents per pound ....

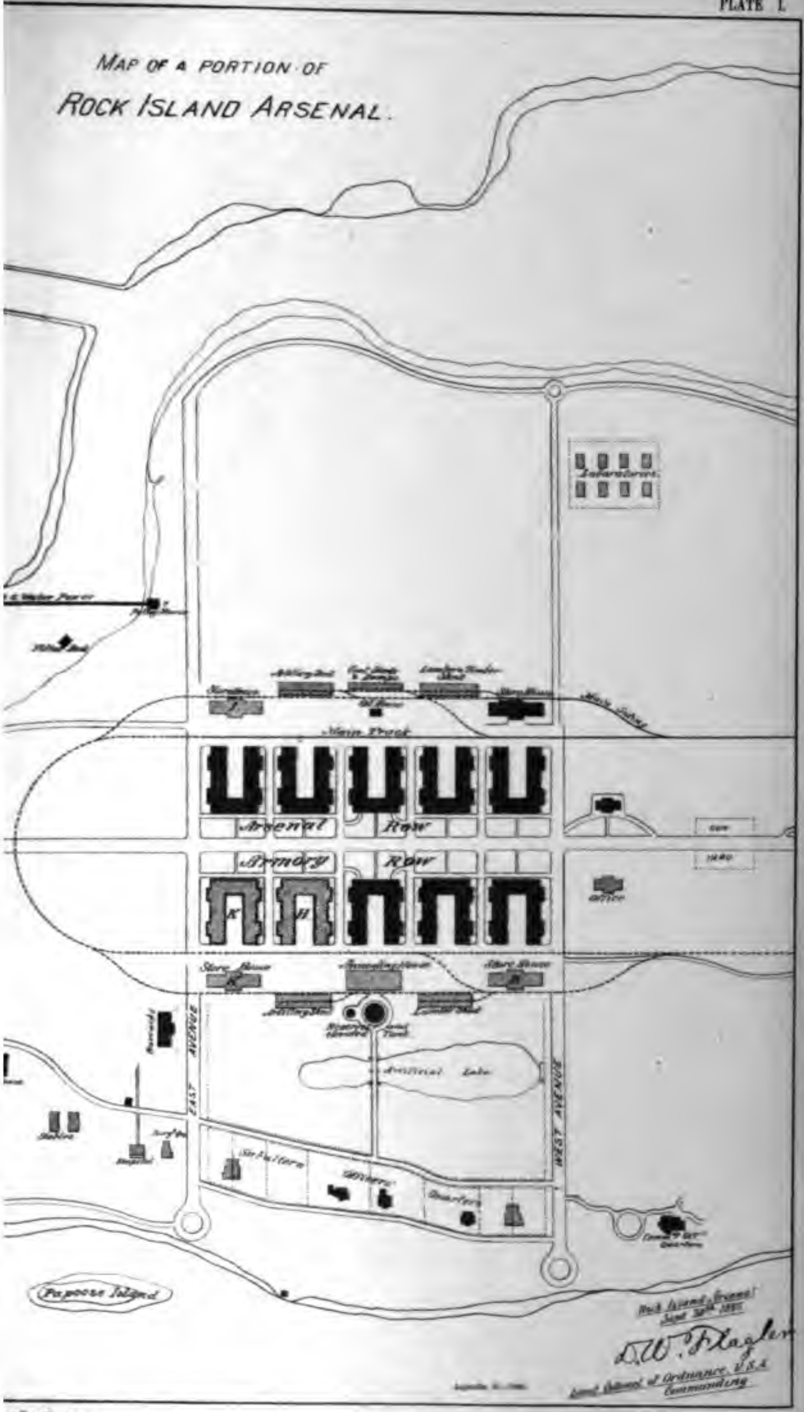
Labor and general expenses ....

Cost per target, $\frac{7}{10}$ cents.

The capacity of tools now on hand is sufficient for making per day: 95 D, 250 F, targets; 250 D, 350 E, 550 F, target cloths; 2,000 D, 2,500 E, 3,000 F, targets.

Respectfully submitted.

D. W. FLAGLER,
Lieutenant-Colonel of Ordnance, Commanding.


MAP OF A PORTION OF
ROCK ISLAND ARSENAL.
Laboratories
Water Power
Main Track
Main Siding
Oil House
Arsenal Row
Armory Row
K
H
Office
Store House
K
Store House
B
EAST AVENUE
WEST AVENUE
Barracks
Artificial Lake
Stables
Hospital
Quarters
Comm'g Off'r's Quarters
Papoose Island
Rock Island Arsenal
D. W. Flagler
Lieut. Colonel of Ordnance, U.S.A.
Commanding

pt2 v3 49 I

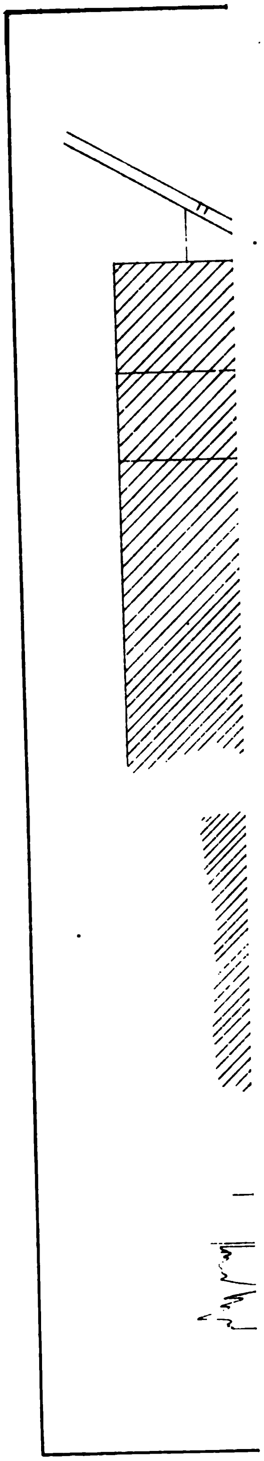
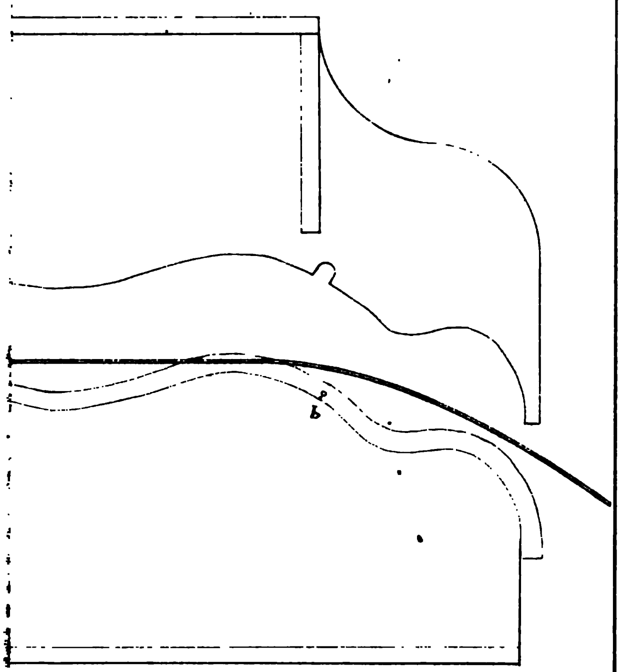


Fig 3



NDING MACHINE.

land Arsenal
f Skirmish Targets.

Rock Island Arsenal
September 30th 1885
D. W. Flagler.
Lieut Colonel of Ordnance U.S.A.
Commanding.

APPENDIX 52.

DESCRIPTION OF THE METHOD EMPLOYED IN ATTACHING THE SIGHTS TO THE 8-INCH RIFLES.

BY CAPT. C. W. WHIPPLE, ORDNANCE DEPARTMENT.

(1 plate.)

The method employed at the Ordnance proving ground for attaching sights to the 8-inch converted rifles is as follows:

The gun is mounted on skids and leveled as regards the axis by a "gunner's quadrant" applied to the face of the piece; a wooden saddle is then seated on the trunnions (see sketch 1) upon which is placed a spirit-level, and the gun is then leveled as regards the axis of the trunnions. Having verified these adjustments, "the line of metal" is determined in the usual way by establishing two points (front and rear) with the "gunner's level" and tracing a line between them.

With guns converted to rifles by insertion of tube through the breech, the center of the breech is indicated on the plug. With "muzzle-insertion" guns carpenters' calipers are used for determining the center of the breech, as follows: the paint is carefully scraped from the cascabel at the extremities of the horizontal and vertical diameters; the calipers, being set approximately to the radius of the breech, are applied from the extremities of both diameters so as to scratch lines near the center; these lines form the sides of a square, the diagonals of which intersect at the center of the breech.

THE REAR-SIGHT SEAT.

A carefully planed rectangular wooden board 12.625 inches deep (the height of the seat for breech-sight above axis of gun) is then suspended at the breech by two cleats bearing at either side on the cascabel in such a manner that the lower horizontal edge shall be at the center of the breech* (see sketch 2). It is leveled by applying a spirit-level to its upper horizontal edge and made vertical by the use of the plummet. On this board (or templet) a vertical line is drawn at a distance of 8.775 inches from the center, and the intersection of this line with the upper horizontal edge of the templet determines the position of the seat for the breech-sight. The curvature of the breech enables the seat to be located and supported by hand, and, the templet having afterwards been removed, the hole for one screw is marked, the seat removed, and this hole drilled and tapped. The seat is then secured by

---

* The templet, shown in sketch 2, must of course be cut away when used with "breech-insertion" guns so as to override the projecting plug.

The breech-sight is then inserted in its seat and a cord from the zero of the scale to a point on the offset at the mu inches from the axis. This line should of course be level, whi ified by the spirit-level. The front sight is then adjusted by a distance of 54 inches from the rear sight and so that its e touch and coincide in direction with the taut cord; the screw marked, the sight removed, holes drilled and tapped, and then attached.

PLATE I.

Fig. 1

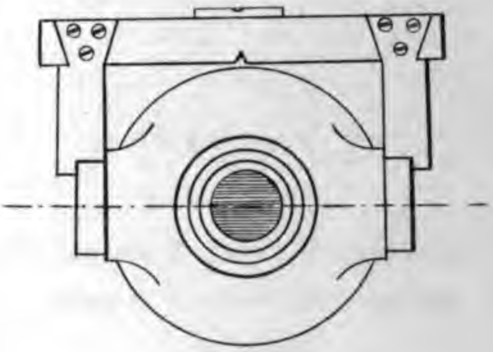


Fig. 2

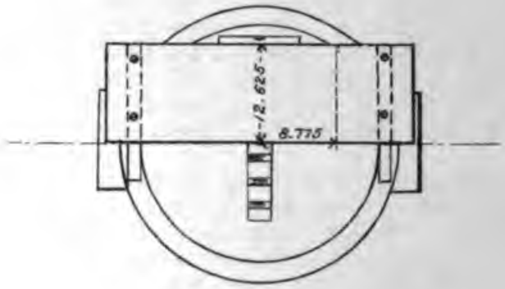
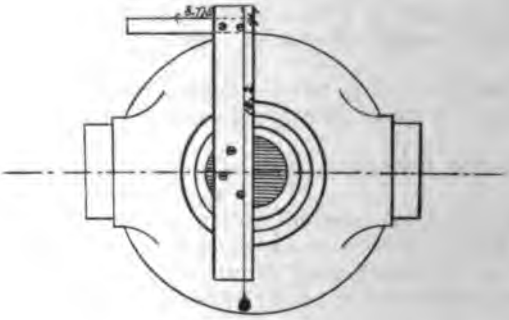


Fig. 3



Appendix 52—1885.

APPENDIX 53.

REPORT ON THE POLE-LIFT FOR FIELD-ARTILLERY CARRIAGES.

BY CAPT. W. L. HASKIN, FIRST ARTILLERY.

(1 plate.)

PRESIDIO OF SAN FRANCISCO, CAL., *August* 1, 1885.

CHIEF OF ORDNANCE, U. S. A.,
Washington, D. C.:

SIR: I have the honor to state that I returned to this post on the 15th ultimo, with my battery, from a practice march of 408 miles.

Two of the 3.2-inch B. L. converted rifles mounted on steel carriages were taken with us. I did not take their limbers, but used the wooden ones of the 3-inch guns. We encountered all the difficulties that we would be apt to meet in campaign, and went over the steepest grades that the battery has ever crossed, all without injury to man, horse, or vehicle.

I inclose a photograph of the pole-lift, constructed for me at Benicia Arsenal, by your authority, for use on this trip, and report that it perfectly fulfills its object. I had no neck-sores, nor any galls that could not be entirely cured in one or two days. The difference, in this respect, between my experience of last year and particularly of this year, as compared with Major Sanger's experience in 1883, is very marked. No light battery should make any long march without these lifts. They take the weight of the pole from the necks of the wheelers, and save the horses from all the bad effects due to the thrashing of the pole up and down as gullies or gutters are crossed. To remove them, it is only necessary to unhook the chain—either before or behind the limber—and they can be thrown off at once. When the end of the pole is raised this is easily done.

In order to diminish the weight on the pole I shifted the knapsack straps to the rear of the limber-chests and hung a rack there for the knapsacks.

This also made more room for the legs of the men and made the chest a more comfortable seat for them.

I could not do this on the new iron limbers, nor could I use the pole-lift on the one of them which is re-enforced with a band of metal projecting above the lid and crossing it from front to rear on its middle line. It was for these reasons that I did not take the new limbers with me.

The new carriages are not provided with long sponges, nor with any hooks or loops upon which they could be carried. After a day's firing it is absolutely essential that the whole bore of the gun should be cleaned,

Having the belief that it was necessary to keep the *breech* u
covered, I had *covers* made of heavy canvas and leather, bu
before we started out that the steel rusted much worse when t
were on than when it was wholly without such protection, an
ingly I removed them.

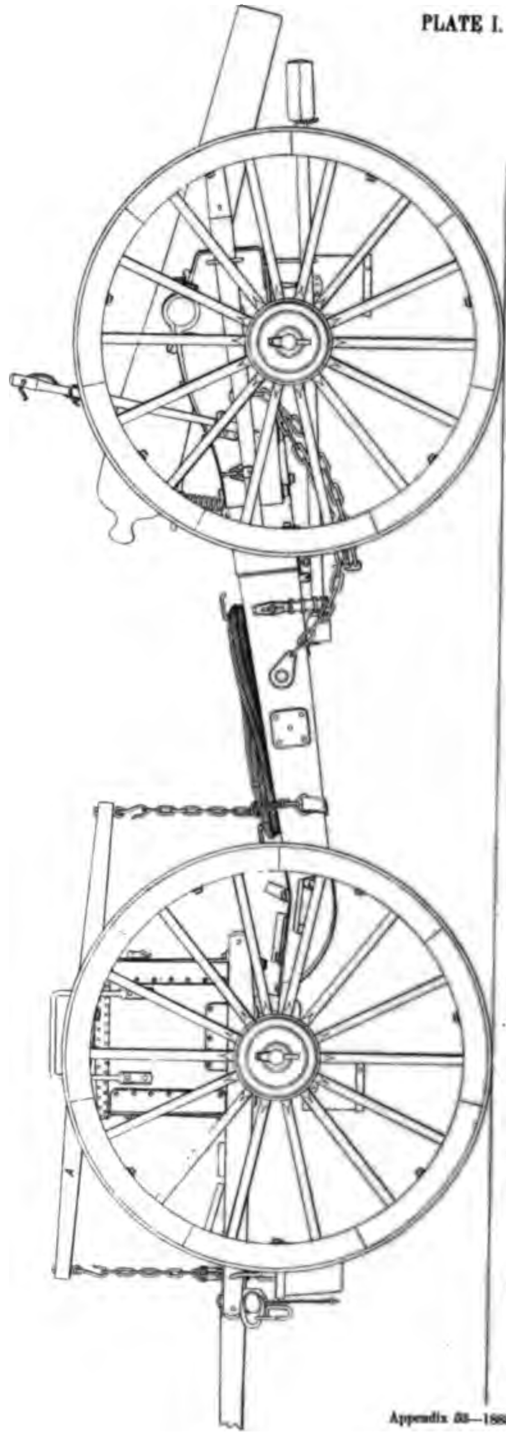
We were absent five weeks, and the breech mechanism did
at any time for want of cover.

I am, sir, very respectfully, your obedient servant,

WM. L. HASK

Captain, First Artillery, commanding Light Ba

PLATE I.



A. - POLE LIFT FOR FIELD CARRIAGES.

Appendix 38—1886.

H Exl pt2 v3 49 1

APPENDIX 54.

EPORT OF THE CONSTRUCTION OF EXPERIMENTAL CARRIAGE AND LIMBER FOR GATLING GUN, CALIBER 0.45 INCH, MODEL 1881, AND OF CART FOR DISTRIBUTING SMALL-ARM AMMUNITION ON THE FIELD OF BATTLE, AT WATERVLIET ARSENAL, DESIGNED BY CAPT. E. B. WILLISTON, SECOND U. S. ARTILLERY.

BY LIEUT. COL. A. MORDECAI, ORDNANCE DEPARTMENT.

(3 plates.)

WATERVLIET ARSENAL, N. Y.

The experimental gun carriage and limber for Gatling gun, caliber .45 inch, model 1881, fabricated at this arsenal in 1881 and 1882, were odifications of those of previous patterns, proposed by Capt. (now ajor) E. B. Williston, Second U. S. Artillery.

The features desired in this construction, and also those for the am- unition cart for distributing small arm ammunition on the field of attle, proposed by Captain Williston, and manufactured about the ame time, are set forth in the following papers:

WASHINGTON, D. C., *September* 8, 1881.

he CHIEF OF ORDNANCE U. S. ARMY,
Washington, D. C.:

GENERAL: The method of packing ammunition and feeding machine guns proposed y Captain Greer, Ordnance Department, U. S. Army, and recommended for adoption y the Light Artillery Board, necessitates radical changes in the system of supplying mmunition I have had the honor to submit (see my report dated March 20, 1880), and I have simplified the plan, notwithstanding that I have extended it so as to em- race the supplying of infantry and cavalry in battle as well as the machine gun, ereby making the system complete, I very respectfully request that I may be per- itted to confer with the commanding officer of the Watervliet arsenal, with a view constructing at that arsenal a cart, one set of harness, and one set of pouches, for e in packing the cart horses when circumstances prevent the carts from being used.

I have been prevented from submitting the details of this system, as improved, ith the required drawings, and I would prefer to await the results of a consultation ith Colonel Buffington before furnishing them, as I am still undecided as to some of e minor parts of the construction.

The results of the trials which I have made with the ammunition-supply cart already rnished to me warrant my expressing the belief that, in case this important system tried, the results will prove satisfactory, and will simplify the problem of supply ow rendered of great consequence by the introduction of the breech-loader and the achine gun, and the proposed adoption of a magazine-rifle.

If possible, I would like to have the cart, the harness, and the pouches made in me to submit them to the Light Artillery Board.

Very respectfully your obedient servant,

EDW'D B. WILLISTON,
Captain Second Artillery.

[First indorsement.]

ORDNANCE OFFICE, *September* 9, 1881.

Respectfully referred to the commanding officer of Watervleit arsenal, who will onfer with Colonel Williston on the subject matter of the within communication nd other kindred subjects. He will, as soon as possible, report on the changes to be

REPORT.

GUN CARRIAGE AND LIMBER.

Col. E. B. Williston proposes to have built one carriage differing fr
model of carriage for Gatling guns made at Watervliet arsenal, provided t
has all the latest improvements, which it has, so far as known, at Waterv
excepting the modifications described below of the changes proposed
Greer, Ordnance Department, in the size and manner of filling limber-bo
on gun axle; in substituting for splinter-bar double and whiffle trees;
brake for down hill which shall also be a mud-scraper for wheels, descr
in having trail hand-spike hinged to the trail, and, in so far as the differe
permit, have this carriage so made that future constructions of carriages
ner machine guns shall be like it. He desires, also, whatever additions
essary to enable him to carry on the Carriage or limber, and in the ma
the following articles, viz:

Feed-guides, outside of limber and gun boxes; intrenching tools; wa
(two of galvanized iron, painted olive to rim) on foot-board of limber
rings; a small grease-can holding wheel-grease and a small shovel or
tween the limber-hounds; a picket rope 3 inches girth, 40 feet long, with
end on curved hooks under the limber-axle: the necessary spare parts an
ments somewhere outside of limber and gun boxes; in like manner a mon
cotton waste, and a brass oiler.

He wishes also all wood parts to be oiled instead of painted; the gun to
the rear sight of Gatling gun to be the same as the Gardner, and the fr
the Gardner, but finer at the point, and made to fold down when not in u

When, in April last, work was suspended on the 14 Gatling carriages,
construction at Watervliet arsenal, the limber-boxes and boxes for gun
fully completed, with the exception of putting in the fillings, which w
made.

The changes proposed by Captain Greer cannot be applied to these bo
were too small; but the limber-boxes can be made to carry 10,080 rounds
than the proposed box—without other alteration than putting in partition
to take up some unnecessary *play* of cartridge packages, thus dispensin
proposed drawers. Those of the Lowell carriage at Watervliet weigh, w
18¼ pounds, which add to the weight to be carried and are otherwise ob
The gun axle-boxes are too small to carry, in packages, each more than
rounds, but boxes can be made whose interior dimensions, without parti
exceed these but 0.025 inch (height) by 0.7 inch (depth) by 1.2 inches (widt
each 2,560 rounds, together 5,120—800 less than Captain Greer's boxes or
making the sum total for each gun (10,080 + 5,120 = 15,200) 400 more
which Captain Greer's plan, so far as understood, does not, the necessa

reater facilities for using it in action, and desires for the carriage to be built for him, mber-chest and boxes for gun axle as follows, viz: Limber-chest of about the same imensions as those last made at Watervliet arsenal for the Gatling carriage, the in- rior to be divided by partitions the full height of chest, into six compartments, ach to hold 1,680 rounds packed in the feed-cases proposed by Captain Greer.

In each compartment there will be a "follower" for retaining in place the cart- dges, whether the compartment be wholly or partially filled.

Boxes for gun axle (each to carry 2,560 rounds, also in the proposed feed-cases, ither in one or two compartments, to be decided hereafter) to be like those made for ast constructed Gatling carriage, but increased in dimensions as above stated, and astened in like manner to gun axle; the left one immovably with lid across the whole top opening *from* the gun; the right to rotate to the front about on axis near pper surface of axle, with lid on end toward the trail, hinged to the top.

The brake for down hill, desired and referred to above, is the same as proposed, nly lighter, for the 3.20-inch field-carriage; that is, a rod or bar of iron or steel, *eyed* t one end to a strap around the shoulder-washer, the other end being a compara- ively heavy shoe, forged on, so that when held vertically, the shoe, having a flange o go outside of tire, will pass over the tire; from this position, thrown either to the ront or rear, it will break the wheel; to the rear, on the march, it will serve as a nud-scraper.

AMMUNITION CART.

To differ from the one last made at Watervliet arsenal in the following particulars: plinter-bar, hounds, and what corresponds to the fork, to be of iron; wooden-axle ody to be dispensed with; the hounds, of angle iron, to extend to the rear, suitably ent and shaped, to serve as mud scrapers for the wheels; addition of whiffletrees; hafts to be turned round for a certain distance from the ends for the use of the 'shaft-rings" of harness; the body replaced by a low wooden chest, similar to an rdinary cart-body, divided into two compartments, each to carry, packed in the reer feed-cases, 7,500 rounds; this chest or body to rotate to the rear about the axle, o which it is to be suitably attached to permit this motion, and provided with a arrow lid or door on under side next to the rear end, made of about 25-inch steel late, which shall be automatic, opening for the distribution, on the ground, of cart- idges, when the body is tilted to the rear, and closing when drawn back to first posi- ion; to accomplish which operations it is to be provided with (under the control of he driver) ropes and a lever suitably attached to it and the part of cart on which it ests; to have two lids or doors on top, hinged longitudinally, opening from the wheels; to be lined on under side, in rear of axle to the steel door, with 1-inch sheet teel. The means and, essentially, the details to accomplish what is here stated ave already been devised and worked up at Watervliet arsenal. It is desired that he cart shall carry two axes, a spade, a pick, sperm-oil can, a monkey-wrench.

CHANGES IN CART HARNESS.

Substitution of Whitman saddles for both off and near horses for those now in use; f shaft-rings for the hooks, with addition of breeching, traces, and whiffletree for haft-horse, also light strap with snap-hook connecting shaft ring with hame-tug; ubstitution of cavalry for artillery bit (Shomaker preferred), and of hair for web irths for both horses.

All traces to have chains 20 inches long with Woelcken hooks attached to clips, and ll to be permanently attached to hame-tugs; whiffletrees to have rings instead of 'cock-eyes," and collars and hames to be permanently connected, hinged at the top, nd fastened at the breast with a spring-catch.

Pouches for packing ammunition on the horses: To be made of leather and canvas, ewed and copper-riveted, consisting each of a back of heavy leather and two heavy otton, duck or canvas pockets, 7.25 by 12.50 by 15 inches, to carry each 1,000 rounds n the Greer-paper packages.

The leather backs are to be so made as to pass over and attach to the saddle, as on rdinary saddle-bags, carrying a pocket on each side; these pockets to have flap- overs, to be attached permanently at lower inner edge and temporarily at the top y means of eyes in the back of pocket, extended and united with rear of flap (thus oubling the thickness of duck), staples fastened to the leather back and leather strap o pass through staples, as in an ordinary mail-bag; the canvas flap-covers, when ockets are full, to be fastened to the body of pocket in similar manner. They are to e emptied on the ground of contents by removing fastening of flap, fastening of ocket, and allowing it to turn around its lower permanent attachment to the back, t being supported and fall of contents regulated by driver.

ESTIMATES.

For carriage and limber (without equipment of tools, &c.)....................
For ammunition cart (without equipment of tools, &c.)......................
For ammunition harness (exclusive of patent collars and hames) ....
For probable cost (not known) of two patent collars and hames permanently attached, hinged at the top and closing at the breast of the spring catch..
For two pairs of ammunition pouches, at $15 each ....

Total ....

REMARK.—As all the above are more or less experimental, the exact cost can given, and will be more than for subsequent productions after models are once lished.

Respectfully submitted.

A. R. BUFFINGTON,
Lieutenant-Colonel of Ordnance, Comman

[Third indorsement.]

ORDNANCE OFFICE, *October* 1,

Respectfully returned to the commanding officer Watervliet arsenal, approve the money estimated will be remitted. It is not intended that the within recom tions will be strictly carried out. Such modifications as experience during the facture may suggest as improvements may be made, &c.

S. V. BENÉT
Brigadier-General, Chief of Ord

CONSTRUCTION.

The above report of Lieutenant-Colonel Buffington, accomps his indorsement 2, dated September 28, 1881, was the guide by the work was to be done, but as the constructions were made unc eye of Captain Williston, or from his instructions, many dev were made from what was first proposed.

The gun carriage and the limber differ from those of previo tern for guns of the same model in the following points, viz:

CARRIAGE.

(Plate 1.)

(1) The axle boxes for ammunition are smaller and the det their attachment to the axle body are changed. Each box will c 45 or 48 packages of 20 cartridges each, depending upon the r in which they be arranged.

(2) The axle braces are bent to enable the cannoneers to stand to the carriage.

(3) The trail-handspike is of metal, and is attached to the l plate.

(4) Each wheel is provided with a "Buffington" traveling bra ranged for use also as a mud-scraper. There are chains to ret brakes on the wheels when they are serving as mud-scrapers, an ports with spring catches to secure the brakes when not in use.

(5) The wood work is oiled, only the metal work is painted bl

LIMBER.

(Plate 1.)

(1) Instead of 3, there are 2 foot-boards resting flat upon the h

(2) The splinter-bar is of the same length as foot-boards.

(3) The fork extends in front of the splinter-bar.

n evener, with a single-tree at each end, is attached to the fork.

ie pole-prop is held up, when not in use, by a spring clasp on
hound.

second prop is attached to the rear end of the left hound; this
ip by a spring clasp at the rear of the axle body.

'eight at the end of the pole being so much reduced, a prop in
he chest appeared advisable for use when the lid of the chest

ie horizontal part of pintle-hook increased in length, to facili-
bering.

ie chest is increased in size and is divided by vertical partitions
compartments capable of containing 112 packages of 20 cart-
ach, making 13,440 rounds of ammunition on the limber.

', hinged at the bottom of each compartment and secured at the
ı spring clasp, retains the packages in place when the lid may
•

'es in the partitions admit of the insertion of metal plates, " fol-
to prevent undue motion to the packages when a compartment
ve been partly emptied.

ie lid of the chest is, when open, held in a horizontal position
chains terminating in snaps, which, when unhooked, permit the
ll to a vertical position, and allow the cartridges in the front
the chest to be reached more readily.

)n the front of the limber-chest are carried two felling axes
mattock, held by sockets and spring clasps.

e foot-boards are two watering buckets placed in iron rings.

ıth the foot-boards are one shovel and one spade, secured by
and straps with turn-buckles.

The wood work is oiled only, the metal work is painted black.

AMMUNITION CART.

(Plate II.)

ımmunition cart is for supplying additional ammunition to ma-
ıns, but it is especially designed for disributing small-arm am-
n to troops on the field of battle.

neral construction, Plate II, is that of a two-wheeled tip-cart.

'rame consists of 2 wheels, 1 iron axletree; 1 wooden axle
side-rails, 1 cross-bar, and 2 shafts, the right one attached
ross-bar, and to the right side-rail by rondelles, and the left one
o the cross-bar and extending back, mortised into the axle body.

ɔody to the cart, has a lid in two pieces, hinged to the upper
the sides; it is divided by vertical partitions into five longi-
compartments, each of which is closed at the rear by a door
to the rear upper rail of the body.

compartment is the width of the length of the paper package
ıtains 20 cartridges, and by careful packing each will receive
ages in height and 15 in length, making 150 packages, or 3,000
of ammunition in each compartment, or 15,000 rounds in the

ntended that two horses should ordinarily be used in this cart,
one in shafts, the near one to be ridden by the driver; the
f both to be attached to single-trees hooked to the cross-bar.

ttachments for tipping the body and for opening in succession
door of each compartment shown in the plate are controlled
lriver. The cord operating the door-catches extends in a groove

along the under side of the left shaft to its front end, then passes through the shaft and over a pully to the driver's hand. The loop of the cord, whose ends are attached to the lever and its catches for tipping and lowering the body, is brought to the driver from behind; the force which he has, consequently, to exert on this cord being a pull to the rear.

Grooves in the sides of the compartments admit the introduction of sheet-metal slides to prevent too free motion among the packages of cartridges when a compartment may be but partly full.

From each side rail a metal bar extends over the adjacent wheel to serve as a mud scraper.

The lid is covered with heavy canvas, oiled. All the wood-work is oiled only, and the metal parts are painted black.

HARNESS.

(Plate III.)

The harness is of russet leather, with the metal parts blacked.

The "Whitman" saddle is used for both horses. At the rear of each saddle is a hook, on which is placed the single-tree with traces attached, when the horse may be hastily detached from the cart. The single-tree rests upon a pad in rear of the saddle.

A strap over the off saddle supports heavy metal rings, through which the shafts pass, and from which they are readily withdrawn. The harness of this horse is provided with Berry's patent collar, such as is employed in the harness for steam fire-engines.

The harness for the near horse has the saddle equipped with stirrups, and has a breast strap.

AMMUNITION POUCHES.

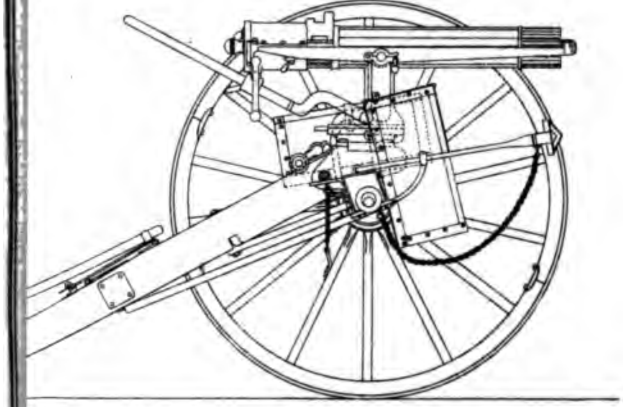
(Plate III.)

For supplying ammunition to troops that cannot be reached by the cart two pairs of canvas bags or pouches are provided. These may be carried habitually on the lid of the cart, and when required (the horses

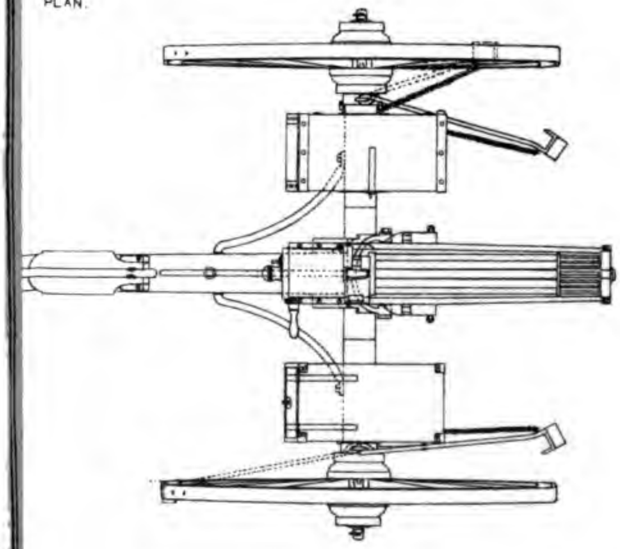
Plate 1.

DEL 1881.

ELEVATION, SIDE, CARRIAGE.



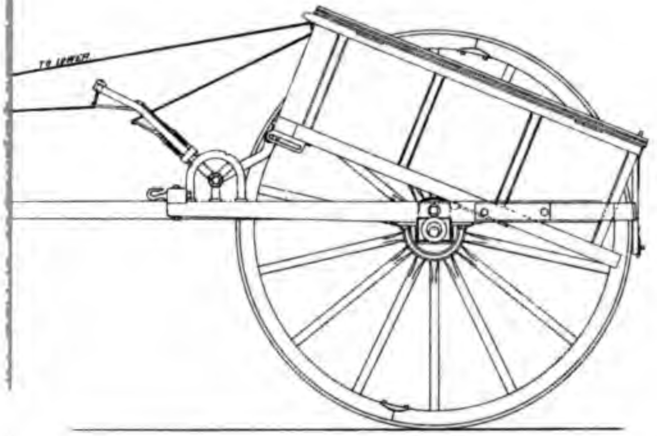
PLAN.

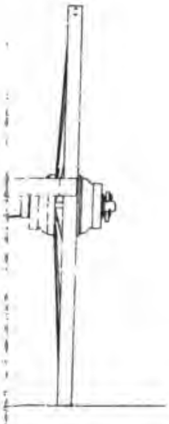


A. Mordecai
Lt. Col. of Ordnance,
Commanding

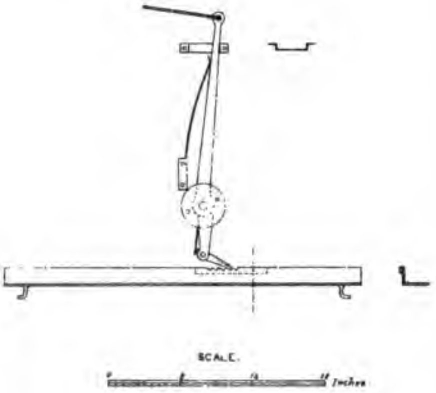
Appendix 54— 1885.

Plate II.





ATTACHMENT FOR OPENING REAR DOORS.



A. Mordecai
Lt. Col. of Ordnance,
Commanding.

Appendix 54—1885.

HARNESS.

(Plate III.)

The harness is of russet leather, with the metal parts blac
The "Whitman" saddle is used for both horses. At the re
saddle is a hook, on which is placed the single-tree with traces
when the horse may be hastily detached from the cart. The
rests upon a pad in rear of the saddle.
A strap over the off saddle supports heavy metal ring
which the shafts pass, and from which they are readily withdr
harness of this horse is provided with Berry's patent collar,
employed in the harness for steam fire-engines.
The harness for the near horse has the saddle equipped wit
and has a breast strap.

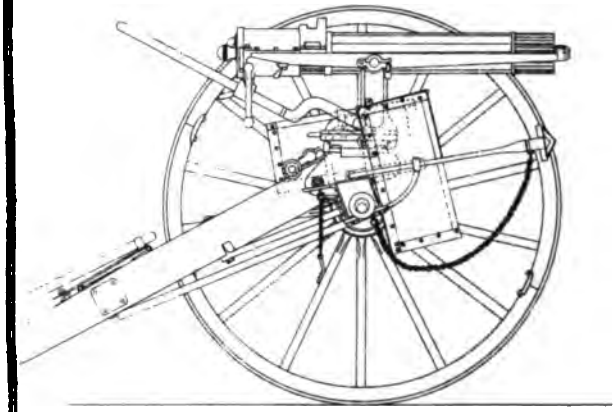
AMMUNITION POUCHES.

(Plate III.)

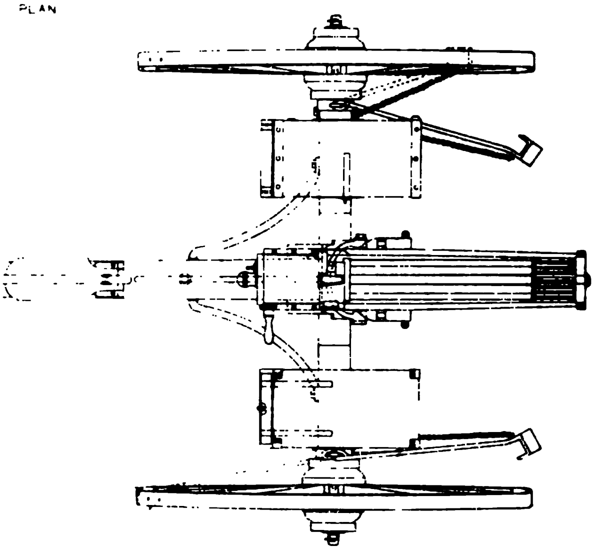
For supplying ammunition to troops that cannot be reac
cart two pairs of canvas bags or pouches are provided. The
carried habitually on the lid of the cart, and when required (
having been hastily detached from the cart), are hung over t
filled from the cart, and sent speedily to their destination.
The pouches are attached at their lower edge permanen
seat piece, of leather, but at their upper edge are secured to
by a strap only, passing through staples.
This strap being withdrawn allows the pouch to rotate abou
inner edge and discharge its contents upon the ground.
Each pouch will hold 50 paper packages of 20 cartridge
1,000 rounds to a pouch, or 2,000 rounds for each horse.
The ammunition-cart with its harness and the ammunitio
were sent to Capt. E. B. Williston at Fort Leavenworth, Kan

DEL 1881.

ELEVATION, SIDE, CARRIAGE.



PLAN



Lt. Col. of Ordnance,
Commanding.

Appendix 54— 1885.

APPENDIX 55.

REPORT OF THE CONSTRUCTION OF GUN-CARRIAGE SADDLE FOR HOTCHKISS MOUNTAIN GUN, CALIBER 1.65 INCHES, AT WATERVLIET ARSENAL, DESIGNED BY CAPT. F. D. BALDWIN, FIFTH U. S. INFANTRY.

BY LIEUT. COL. A. MORDECAI, ORDNANCE DEPARTMENT.

(1 plate.)

WATERVLIET ARSENAL, N. Y.

The mountain gun-carriage saddle, designed by Capt. F. D. Baldwin, Fifth U. S. Infantry, was made at this arsenal in the winter of 1882 and 1883. It was issued to the Fort Abraham Lincoln ordnance depot in April, 1883.

Its construction and use are set forth in the following papers. Some modifications proposed afterwards by Captain Baldwin were adopted. The drawings on the plate show the carriage as constructed:

TECUMSEH, MICH., *August* 29, 1881.

Col. JAMES M. WHITTEMORE,
Acting Chief of Ordnance:

DEAR SIR: I have just completed a model of the gun-carriage saddle, and on your suggestion I forward the same by mail to the Department. I have not had time to complete the description as I should have liked, but sufficiently so that with aid of the model it can be understood. Should there be anything wanting in description, &c., and you will let me know, will try and explain. I have not entered into small details either in my model or description; in fact this model only covers and shows the idea or principle, which must, by actual experiments and trials, be perfected.

I have estimated the weight of gun and carriage at not exceeding 220 pounds. I do not believe, however, that if the carriage is properly made the entire weight will exceed 200 pounds.

The carriage should be made of steel of about one-eighth inch in thickness.

Believing that the subject will receive due consideration at the hands of the Ordnance Department, and requesting information as to disposition and recommendations made,

I remain, with great respect, yours, &c.,
FRANK D. BALDWIN,
Captain, Fifth Infantry.

TECUMSEH, MICH., *August* 29, 1881.

The CHIEF OF ORDNANCE U. S. ARMY,
Washington, D. C.:

SIR: In presenting the inclosed model of a mountain gun-carriage saddle it is with a view of overcoming obstacles found to exist in using the ordinary gun-carriage when it becomes necessary to pack it on mules in mountain warfare, or when it is impracticable or impossible to go on wheels. Its advantages are:

(1) The carriage-saddle, including the Hotchkiss mountain gun, weighing not to exceed 220 pounds, can be packed on one mule, whereas it requires three mules to pack the gun and carriage now used—a saving of two-thirds in transportation.

(2) The gun and carriage-saddle are complete within themselves, and when the one mule upon which it is packed reaches the field, we are ready for action; whereas with the carriage now used it is necessary to get three mules on to the field, and in case

be taken, and it is not my intention, nor would I consider it advisable, with the gun-carriage, excepting under circumstances when the gun can ported on wheels.

Believing that the merits of the gun-carriage saddle will be recognize cers without further comment, I will respectfully submit this model w meager description, requesting that it be presented to the Board of Lig Officers now in session at Washington, D. C.

Very respectfully, your obedient servant,

FRANK D. BALD
Captain, Fift

[First indorsement.]

ORDNANCE O
Washington, Septem

Respectfully referred to the president of the Light Artillery Board, fo tion.

JAS. M. WHITTEM
Acting Chief of

[Second indorsement.]

LIGHT ARTILLERY B
Washington, D. C., Septem

Respectfully returned with the information that the Board has recom one carriage be made for trial.

JNO. C. TID
Colonel, A. D. C.,

[Third indorsement.]

ORDNANCE O
Washington, Novembe

Respectfully referred to the commanding officer of Watervliet Arsenal tion with report of Light Artillery Board, sent him on the 16th inst. M express.

By order of the Chief of Ordnance.

JAS. M. WHITTEMOR
Lieutenant-Colonel of

DESCRIPTION OF THE BALDWIN MOUNTAIN GUN-CARRIAGE

DIMENSIONS.

I endeavored to have the model made to the scale of 1 inch t Not having the exact dimensions of the Hotchkiss mountain doubtedly will be found necessary to modify the top section while in transit, and in case it becomes necessary for the men to carry the gun and carriage by hand, these rings can be turned to the front and rear, the ramrods passed through them at right angles to the carriage, whereby handles are improvised, which will enable the men to move the piece with ease and to points inaccessible for animals.

To provide for the elevation of the gun, a thin plate of steel, fastened to the front cross-bar, extending to the rear under the gun and over the rear cross bar. To regulate the elevation, a wedge is used. At the rear end of the top section is a round iron bar, the ends of which pass through the sides of the carriage and shaped into a crank. A washer is fitted to this bar close to the sides of the carriage, which prevent its spreading. On the inside, attached to this bar, are flanges, which act in the double capacity of preventing the sides from closing in, and, when the lower section is closed together and standing perpendicular, holds the top and lower sections together securely by the flanges passing down into the slots cut out of the saddle-pads. The bend in this bar is to give the necessary room to secure elevation of the gun.

The wooden pads attached to the lower section inside made to fit the aparajoe.

At each end of the lower section are hooks, which are used to prevent the spreading of the carriage when in action. When packing the carriage these hooks will be secured along the side of the carriage by inserting the point of the hook in the eye on the runner.

SEE MODEL.

To be made of $\frac{1}{8}$-inch steel. It may be found necessary to strengthen the rear part of the top section to keep it from spreading or closing.

GENERAL INSTRUCTIONS FOR USING AND WORKING THE BALDWIN MOUNTAIN-GUN-CARRIAGE SADDLE.

Being ready for action, the ramrods removed from the rings, to prepare it for packing on mules—

(1) Turn the cranks on each side around to the front until they stand perpendicular to the sides. This will turn the flanges out of the slots and disengage the sides of the carriage. Then unfasten the hooks at each end of the lower section of the carriage, turning them back and along the side, securing them in the runners. This done, the lower section can be spread.

(2) Spread the base of the carriage about 2 feet, each side equally, then turn the cranks down so that they will lay horizontally with the sides of the carriage. This is necessary to prevent the bar coming down onto the mule's back.

(3). Turn the gun, muzzle to the rear, placing the trunnions in the rear trunnion-beds. The carriage is now ready and in shape to be placed on aparajoe.

It should be lifted bodily to the mule's back, the lower part of the carriage next the mule swinging out horizontally to prop it over the back of the mule, lash and fasten securely, passing the lashings through the openings in the lower sections and not over the runners, as it would have a tendency to spring the sides out of shape and spring apart the top section, besides throwing the pads off the aparajoe, whereas they should be lashed down.

After the carriage is properly packed put the ramrods through the rings in their proper place.

MATERIALS.

The principal parts of this carriage are of Bessemer ste
thick.

The trunnion-beds and cap-squares are of bronze.

A. MORDE

Lieutenant-Colonel of Ordnance, Com

WATERVLIET ARSENAL, N. Y., 1885.

APPENDIX 56.

REPORT OF THE CONSTRUCTION OF METAL LIMBERS FOR SERVICE WITH FIELD-CARRIAGES FOR 3.2-INCH BREECH-LOADING RIFLES AT WATERVLIET ARSENAL.

(6 plates.)

WATERVLIET ARSENAL, N. Y., *September* —, 1885.

The first metal limbers for field-carriages constructed at this arsenal were made for service with a caisson, a battery-wagon, and a forge, each of metal, recommended by the Board of Light Artillery Officers convened by virtue of General Orders No. 39, Headquarters of the Army, A. G. O., Washington, April 28, 1881.

The following extract from the proceedings of that Board expresses its views:

> The pole of the limber to be of wood and the frame of steel or iron, and its wheels interchangeable with those of the piece.
>
> The limber-chests to be of steel, and for the 3.2-inch gun capable of carrying about 40 rounds of projectiles laid horizontally in pigeon-holes or boxes, the cartridges to be carried above the projectiles in water-proof drawers, and the chest provided with two drawers or compartments, one for small implements and the other to be used exclusively for carrying friction-primers. The back of the chest to let down by means of hinges at the bottom, giving access to the interior of the chest; when up or closed to be secured by strong fastenings, and when down to be supported horizontally by straps or other device. The ends of the chest to be provided with handles, as in the the present model, and foot-boards of metal to be provided for cannoniers when mounted on the chest.
>
> That wooden single-trees be fastened to the end of a short splinter-bar, and that the line of traction of the traces be the same as in the present harness.
>
> The pole to be attached to the limber in such manner as to be removed without the use of a wrench, and the attachment of rear to the front carriage by means of a lunette and pintle, be the same as at present, except that the pintle project beyond the limber-chest.
>
> That the front of the limber-chest be provided with a painted canvas boot, to cover the knapsacks carried on the foot-boards.
>
> The boot to be fastened at the top by means of eyelets and a half-inch strap running through staples and eye-pin riveted to the chest, and at the corner by straps passing over eye-pins, the ends of all the straps to be protected by metal. (See Plate 1.)
>
> The position of the pintle, the position of the ammunition-chest with reference to the axle, and the lift of the trail in pounds will all more or less determine the weights on the collars of the wheel horses, as well as the dimensions of the turning angle.
>
> These cannot be accurately determined by the Board without experimenting with the carriage itself, and it is thought that while it is advisiable to only refer to these matters in a general way, it is recommended that the pintle be not placed under the chest that the turning angle be as large as practicable without greatly increasing the length of the piece limbered, and that the weight at the end of the pole when the piece is limbered be not more than 8 pounds per horse unless absolutely required by the other details of construction.

On November 15, 1881, the preliminary report of the Board was forwarded by the Chief of Ordnance, U. S. A., to the commanding officer of this arsenal, with directions to report specifically his views in regard to the samples to be made with estimate.

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> That the front of the limber-chest be provided with a painted canvas boot, to cover the knapsacks carried on the foot-boards.
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> The boot to be fastened at the top by means of eyelets and a half-inch strap running through staples and eye-pin riveted to the chest, and at the corner by straps passing over eye-pins, the ends of all the straps to be protected by metal. (See Plate 1.)
>
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> These cannot be accurately determined by the Board without experimenting with the carriage itself, and it is thought that while it is advisiable to only refer to these matters in a general way, it is recommended that the pintle be not placed under the chest that the turning angle be as large as practicable without greatly increasing the length of the piece limbered, and that the weight at the end of the pole when the piece is limbered be not more than 8 pounds per horse unless absolutely required by the other details of construction.

On November 15, 1881, the preliminary report of the Board was forwarded by the Chief of Ordnance, U. S. A., to the commanding officer of this arsenal, with directions to report specifically his views in regard to the samples to be made with estimate.

Rubber packing will probably have to be used to render the chest of tight. The objection to horizontal pigeon-holes for projectiles is the reaching those behind the front row. This will be found to exist with th arrangement last proposed. The front frame, after being emptied, has to and deposited somewhere before the projectiles in rear can be reached. I frame would probably be thrown on the ground and never be seen again.

As the pintle hook in the limber is to project in rear of the chest, there difficulty in having the back of chest let down properly, and it will be venient to reach across it to the rear row of projectiles.

As the chest is divided into two parts, it is proposed to make the back in each hinged at its upper edge so as to open back on to top of chest, th only half the contents at one time.

The limber and chest for gun-carriage, caisson, battery wagon, and forg of the same material and construction, for the last two drawers will be tools and small stores, and for this a back in two pieces will also be fo tageous.

The action of the Chief of Ordnance on these recommend that—

(1) Iron should be used for the body of the limbers.

(2) The trail of the gun-carriage should have a bearing in f pintle.

(3) Steel should be employed in the limber chests.

(4) My discretion to be used in the arrangement of the in the lid of the chest, but that one chest should be fitted up on dorn plan, and that the top of pintle should not be made to pro the bottom of the chest the back of chest could be let down pintle.

LIMBER BODY.

(Plate I.)

The principal parts are:

1 axle, steel, 3 by 2½ inches.
2 hounds, iron, angle, 2½ by 2½ inches by ¼ inch.
1 fork, iron, of 2 T bars, 2½ by 2½ inches by $\frac{5}{16}$ inch.
1 splinter-bar, iron, angle, 2½ by 2½ inches by ¼ inch.
2 foot-plates, steel, $\frac{3}{16}$ inch thick.
1 pintle hook, iron, with eye for rear prop.

1 pole key, iron.
1 pole-key clasp, steel.
2 clasps for props, steel.
2 single-trees, wood.
2 draught-hooks, iron.
2 wheels, "Archibald."
2 linch-washers.
2 linch-pins and clasps.
2 staples, iron, riveted to hounds, to receive stays of ammunition chest.
2 bolts, low steel, for pintle-hook.
6 bolts, low steel, for axle-straps.
2 bolts, low steel, for securing chest to hounds.
Rivets, iron.

CONSTRUCTION.

The axle is attached to the hounds and fork by bolts, through the axle-straps.

The splinter-bar and the foot-plates are united to the hounds and fork by rivets and by the fork-strap and corner-irons. The draught-hooks are riveted in the corner-irons.

The pintle-hook and the braces are attached by bolts.

The clasps are connected by rivets. A piece of sheet metal riveted to the splinter-bar and the front foot-plate forms a receptacle for cans of axle grease.

The canvas boot in front of the ammunition chest is secured to the limber body by four straps passing through slots along the rear of the front foot-plate; and is attached to the chest in front by 6 hooks, and at each end by 2 buttons.

The ammunition chest being so placed as to diminish the weight at the end of the pole, a rear prop appeared advisable for use with chests opening in rear.

In the first limber made, angle iron was employed instead of T iron for the fork, but as the latter was found to furnish a better attachment for the pintle-hook, it was used in the field limbers made subsequently.

As all the chests were not of the same dimensions, the length and width of the limber frames were varied correspondingly.

WEIGHT.

The limber body, with its wheels and pole, weighs 805 pounds.

AMMUNITION CHESTS.

In determining the construction to be adopted in the ammunition chests, the first point to be decided was the thickness of metal to be used.

After such limited experiments as could be made at this arsenal, by firing the 500 grains bullet at plates of different grades of steel and of different thickness at distances varying from 300 to 1,200 feet, and after corresponding upon the subject with General J. C. Tidball, U. S. Artillery, who had been the president of the Light Artillery Board of 1881, 0.12 inch was fixed upon as the thickness of steel for the chest. This, it was found, would offer sufficient resistance at 500 yards, the limit suggested by General Tidball, would make a strong, stiff chest, and one of not unreasonable weight.

each chest had, therefore, to be arranged to suit the metho
ployed in it.

The first order for fabrication contemplated three chests
for use with a caisson, one for a battery wagon, and one f
and as the first had to be fitted after the method proposed b
Hagadorn, these three chests were made of the same size a
opening to the rear, the side being hinged at the bottom a
down.

When, later, instructions were given to fabricate six addi
bers for use with carriages for 3.20-inch wrought-iron B.
other methods of packing the ammunition were devised at t
and used in the chests.

In some of the first chests the bottom and ends were m
piece; but as the fitting of the plates was found very trouble
side in the subsequent chests was a single piece.

For all the chests homogeneous steel, from Park Brothe
Pittsburgh, was used in the top, as this piece was bent do
four sides to stiffen the projecting edges, and in the chests
the rear a flange also was turned by which the top was riv
sides of the chest. This metal was bent cold; the other m
found could not be so treated with safety, even when heate
facilities at hand.

In all the chests rivets only were used to unite the parts.

To render the chests water-tight, a packing-box—a narrow
metal—extends around the open side. In this is placed rub
against which the lid closes and is pressed tightly by the
In the chests opening on top the packing-box is without
sides, while in those that open to the rear the packing-box
is within.

Several styles of fastening for lid of chest were made, b
was that devised by Lieut. W. B. Gordon, Ordnance D
shown in detail on Plate 3. It operates by an eccentric, an
alone on all the chests except that of pattern No. 1, Plate 2.

The lid of the chests that open to the rear is held, whe

CHEST OF PATTERN NO. 1, HAGADORN'S.

(Plate II.)

The projectiles in this chest are carried in four trays, 11 inches each. The cartridges are in two drawers above the projectiles, and for the friction primers is provided, in each drawer, a box with a lid.

The trays are composed of a piece of sheet metal, forming the bottom and ends; of three curved pieces, and a head-rest and a tail-rest that support and confine the projectiles; of bronze castings that act as separators to the curved sheets; of tie rods and braces to stiffen the construction; of rollers to facilitate moving the loaded trays, and of spring catches by which they are held in place.

The head-rest is formed of two plates, confining rubber rings that receive the forward ends of the projectiles. The tail-rest, of metal or wood, has a rubber strip on its upper surface, on which the lower tier of projectiles rest.

When a front tray has been emptied, it is withdrawn and exchanged with the full one behind it.

The cartridge-drawers rest upon pieces of angle-iron. They are of copper, stiffened on the bottom by sheet-iron, bent to form ribs, and riveted to the copper. Stops on the under side of the top of the chest prevent the drawers from being drawn out entirely. One drawer has two flat fixed handles, over recesses; the other has two movable wire handles, closing into depressions. The lids of the primer boxes are controlled by springs.

CHEST OF PATTERN NO. 2.

(Plate III.)

The filling for this chest was suggested by that proposed by Mr. Hagadorn several years before for the wooden ammunition-chest. One half of the chest is fitted with metal partitions for 23 projectiles, resting point downward on rubber rings; the other half contains cylinders of paper, in which the projectiles are placed, resting on rubber rings.

The metal partitions are riveted to a band of sheet metal, and are separated and stiffened by braces riveted to them. The partitions are stiffened in themselves by being wired along their upper edge.

The paper cylinders are united by rivets and bolts, and have no band between them and the chest.

A compartment in the center of the chest, between the projectile-holders, contains some of the cartridges, and the remainder are stored in three trays, which, supported above the projectiles by pieces of wood and metal at the front and rear of the box, can be moved sideways and allow the projectiles to be reached without the trays being removed. The space toward the center between two trays carries the equipments for the gun.

The metal parts of the filling and the trays are of galvanized iron, which is also used for the same purpose in all the chests.

On the rear of the chest (front when on the limber) are sockets and spring clasps for two felling-axes and for two watering-buckets; the bails of the latter, passing up between the chest and the foot-board, are hooked to the chest. This is the same for all the chests except No. 1.

On all the chests, except No. 1 and one of Pattern No. 2, the lower end of the front branch of each handle (see Plate IV) is turned into a hook for carrying the prolonge; the rope is passed back and forth over

the hooks and under the chest and hounds in rear of the axle, an
loose end, if not reaching a hook, is lashed where it may come t
rope.

Chest of Pattern No. 3.

(Plate IV.)

The filling of this chest is a modification of that of Hagado
Pattern No. 1.

The projectiles are horizontal in the trays instead of being in
The rear trays are bolted in the chest, the front ones only bein
able. These, when emptied, are withdrawn and kept on the ope
on the top of the chest while the projectiles in the rear trays ar
removed.

Two trays are entirely of metal, the other two of paper cy
within a metal band. The front trays have metal backs to supp
rubber rings. Rods across the open spaces at the ends of th
serve as handles. No rollers or catches are used, and the vertical
of a tray is prevented by rubber washers riveted on top.

Two compartments above the projectiles contain the cartrid
equipments. The front of these spaces is not entirely closed, b
half of each front is hinged. When closed it is retained by a
catch at each end.

The trays contain the same number of projectiles and are much
and less expensive than Hagadorn's. They are similar to the ho
chest of Pattern No. 2.

Chest of Pattern No. 4.

(Plate V.)

The projectile-holders in this chest were suggested by some
the Italian artillery.

Each half of the chest is divided by vertical partitions into fo
partments of one size, and a fifth larger; in each of the first
placed a sliding holder, which contains five projectiles, separ
two points by semicircular bands of iron, and resting, point dow
on rubber rings. A dropping handle is attached to the front
holder.

The two compartments adjacent to the center partition are p
each with a copper box, with lid, for friction primers. These
carry also the equipments for the gun.

The cartridges are packed in two compartments above the
tiles; a portion of the front of each is hinged and has two d
handles; when closed these plates are held by spring catches
ends; the hinges are formed to prevent the fronts falling muc
the horizontal, so that they are closed by the lid of the chest
is raised.

Chest of Pattern No. 5.

(Plate VI.)

The left half of this chest and the compartments for cartrid
identical with pattern No. 4; the filling in the right half was d
by Lieutenant Gordon, Ordnance Department.

In this last method the first tier of projectiles is placed upo
on the bottom of the chest, six in the rear row, base to the re
five in the front row, base to the front. The bolts in the proje

rear row enter holes in a fixed plate, the bolts in those of the front enter holes in a movable binding-plate, and the points of the pro- iles of both rows enter holes lined with rubber in a second movable ding-plate. These plates are hinged to the bottom of the chest, and en raised press firmly against the projectiles, and are held by spring ches, the levers of which extend to the front of the chest (rear, the est being on the limber).

The second tier of projectiles, arranged in all respects similar to the st, is supported on a shelf riveted to the chest.

Above each tier is a space proposed to be utilized for the equipment.

This filling is very expensive, and was not found so satisfactory as had en hoped; therefore it was introduced in only one-half of one chest. stores the projectiles more compactly than any of the other methods, t in many respects is objectionable.

CAPACITY OF CHESTS.

	Rounds.
tern No. 1	44
tern No. 2	46
tern No. 3	44
tern No. 4	40
tern No. 5:	
Right half	22
Left half	20

WEIGHTS OF CHESTS, WITH FILLING.

	Pounds.
. 1	330
. 2	292
. 3	315
. 4	347
. 5	351

Either chest without filling weighs about 218 pounds.

DISPOSITION MADE OF LIMBERS.

One limber with chest No. 1 and one limber with chest No. 2 issued Light Battery F, Fifth United States Artillery, Fort Hamilton, New rk Harbor; one limber with chest No. 2 and one limber with chest . 4 sent to Benicia Arsenal, California, for use of Light Battery K, rst United States Artillery; one limber with chest No. 3 sent to ited States Military Academy, West Point, N. Y.; one limber with est No. 3 sent to United States Artillery School, Fort Monroe, Va.

Chest No. 5 was issued on limber of caisson to Light Battery F, Fifth ited States Artillery, Fort Hamilton, New York Harbor.

COST.

Each limber and chest, complete, with filling, cost about $650; but as ey were entirely experimental, and as the work was commenced with- t perfected drawings or designs, much expense was incurred in ex- rimenting and in alterations, in learning the workmen, and in tools; erefore the figures given are much above what such constructions uld cost when made by the quantity after the pattern may have been lly determined.

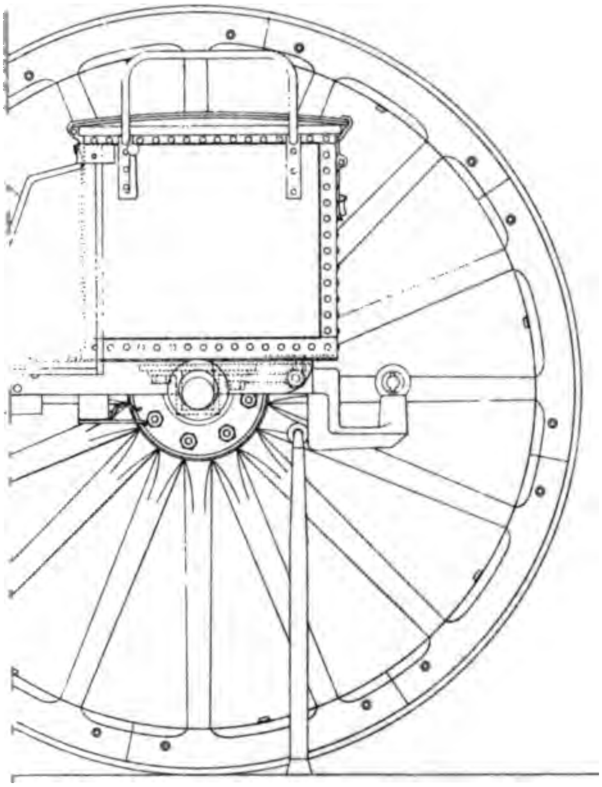
A. MORDECAI,
Lieutenant-Colonel of Ordnance, Commanding.

WATERVLIET ARSENAL, NEW YORK, 1885.

Plate 1

ES.

ELEVATION, SIDE.



Appendix 56—1895.

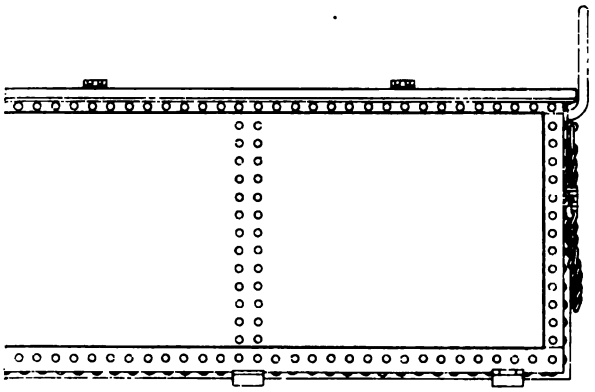
A Mordecai
Lt. Col. of Ordnance,
Commanding

H Ex

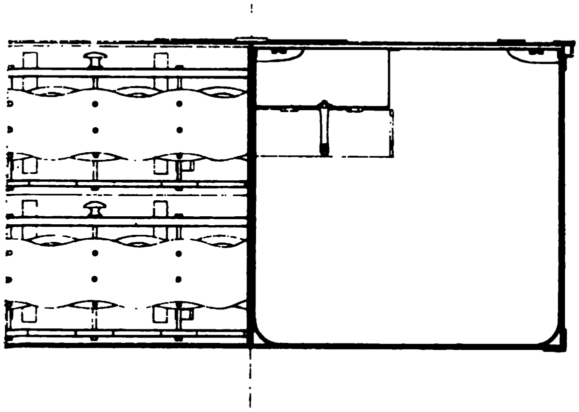
Plate II.

LIMBER

REAR ELEVATION



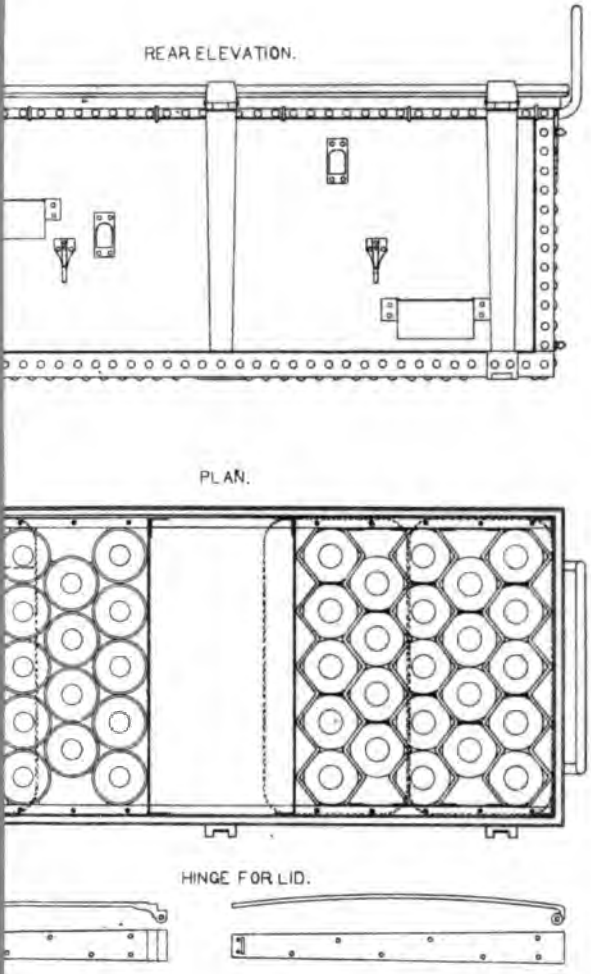
PROJECTION



A. Mordecai,
Lt. Col. of Ordnance,
Commanding.

Appendix 56—1885.

LIMBER.

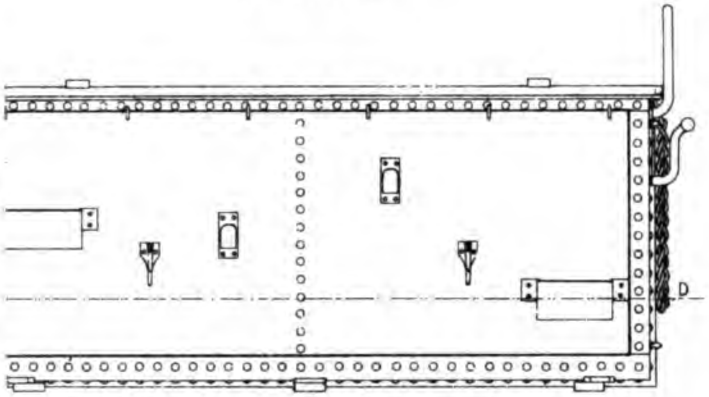


A. Mordecai
Lt. Col. of Ordnance,
Comdg.

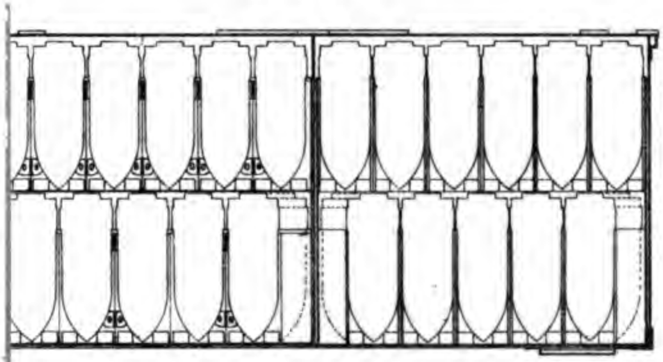
Plate IV.

LIMBER.

REAR ELEVATION.



SECTION ON C-D.



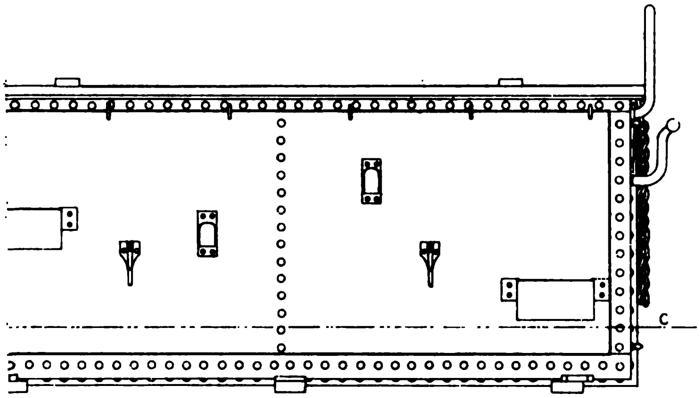
A. Mordecai
Lt. Col. of Ordnance,
Commanding.

Appendix 56—1885.

Plate V.

D LIMBER

REAR ELEVATION.



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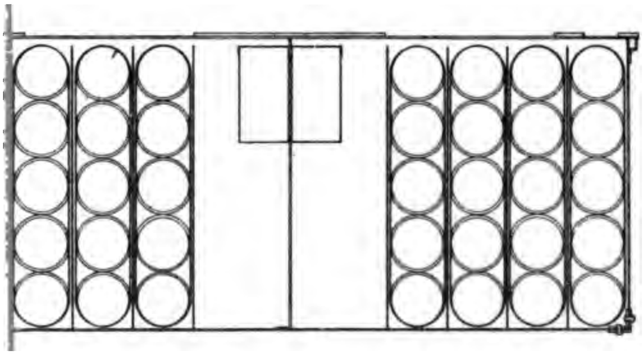
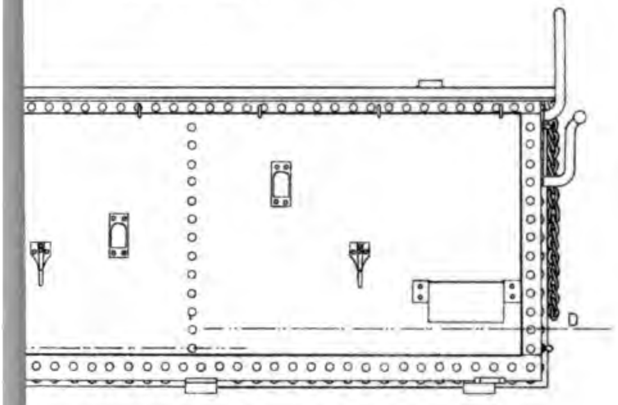


A Mordecai
Lt. Col. of Ordnance,
Commandin

Appendix 58—1886.

MBER.

REAR ELEVATION.



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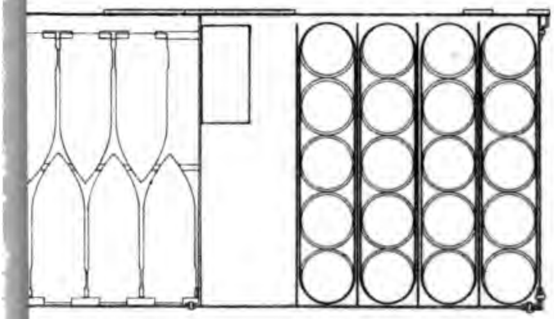


A. Mordecai
Lt. Col. of Ordnance,
Commanding

APPENDIX 57.

RT OF THE CONSTRUCTION OF A FIELD CARRIAGE FOR 3.2-INCH STEEL BREECH-LOADING RIFLE, AT WATERVLIET ARSENAL.

(1 plate.)

WATERVLIET ARSENAL, N. Y.

March, 1884, the commanding officer of this arsenal was directed
ricate a metal carriage for the 3.2-inch steel rifle then in course of
ruction at the Watertown Arsenal.

e carriage made for the 3.2 inch wrought-iron B. L. rifle described
e report of the Chief of Ordnance, U. S. Army, for 1884, Appen-
4, was taken as the model, and such modifications adopted as were
nded by the differences in the gun to be used.

the steel rifle was to have the French breech closure, instead of
erman one used in the 3.2 inch converted rifles, the elevating ap-
tus had to be remodeled, that it could in no way interfere with the
ing of the breech. This was accomplished by removing the hand-
l and axle that operated the elevating screw, and substituting a
, shaft, pinion, and small gear, so that the power would be applied
e right side of the stock.

wooden handspike and socket were substituted for the iron hand-
, and the axle plates were reduced one-sixteenth inch in thickness,
roposed by the Ordnance Board (Report of Chief of Ordnance for
page 315).

the original construction the steel cheeks were not changed.

the parts that differed from those of the model carriage are shown
tail in the plate.

carriage was completed in the month of June, and sent to the
y Hook proving ground. Sixty rounds were fired from it by the
ance Board, and some additional rounds by the "Board for Test-
ified Cannon," &c.

October 1 the Ordnance Board reported that the carriage had
way so far as to render repairs necessary before further firing
be made.

commanding officer of this arsenal was then directed to proceed
dy Hook and confer with the Ordnance Board in regard to what
tions would be most advisable. It was decided that the principal
e should be in the substitution of longer cast-steel cheeks for
in the carriage.

injury was in rear of the cheeks, the trail and cheek plates having
ed and bent outward to such an extent as to render the carriage
viceable.

carriage having been returned to this arsenal, cheeks of cast steel,
in plate, obtained from I. G. Johnson & Co., Spuyten Duyvil, N

Y., were introduced, and some minor repairs made. The left jo box of elevating nut had to be cut in two before it could be plac position.

Again on April 11 the Ordnance Board reported "that the steel carriage received back from Watervliet Arsenal, repaired and modi has broken down after enduring 139 rounds."

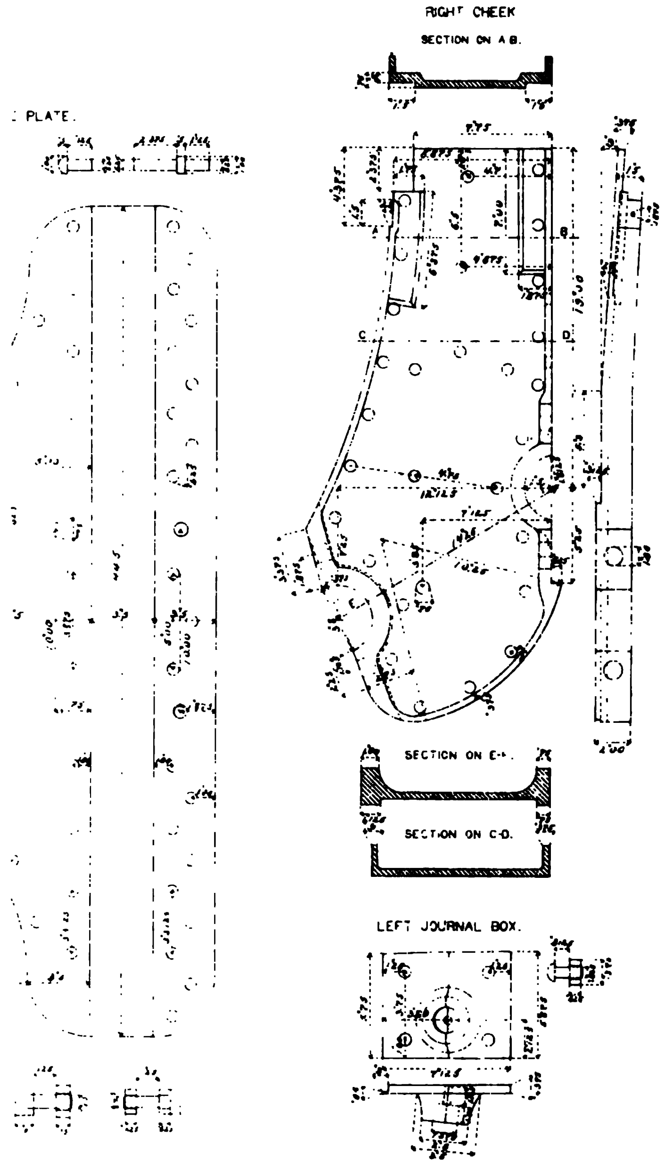
Fracture of the lower angle irons through rivet holes and buck of the trail in rear of the cheeks had taken place, showing weakne construction.

The large charges used with so light a gun caused strains beyond the structure could stand.

The broken carriage has been sent from here to the National Arm that such parts as may be suitable can be used in a carriage of diffe construction being fabricated at that place.

A. MORDECAI,
Lieutenant-Colonel of Ordnance, Commandin

L. RIFLE



Lt. Col. of Ordnance,
Commanding

Appendix 57—1886.

APPENDIX 58.

REPORT OF THE CONSTRUCTION OF A CAISSON AND A BATTERY WAGON OF METAL FOR FIELD SERVICE, AND OF A WAGON FOR AMMUNITION COLUMNS, AT WATERVLIET ARSENAL.

(5 plates.)

WATERVLIET ARSENAL.

The caisson and battery wagon of metal, and the wagon for artillery ammunition, fabricated at this arsenal, were proposed by the Board of Light Artillery Officers convened by virtue of General Orders No. 39, Headquarters of the Army, A. G. O., Washington, April 28, 1881. All the details were worked up at this arsenal.

The views of the Board as regards these carriages, and also in reference to a field forge, are shown in the following extract from its proceedings:

THE CAISSON.

The limber of the caisson to be similar to and interchangeable with that of the piece.

The frame of the caisson body to be of iron or steel, and have a single steel chest capable of carrying for the 3.20-inch gun about 80 rounds of ammunition. The lid of the chest to be movable, instead of the back, and the projectiles to be placed on end, and the catridges to be carried in 8 trays placed over the projectiles. In this connection attention is invited to the Hagadorn system of carrying ammunition, now on trial in Light Battery K, First Artillery.

The chest to be placed in proper position for counterpoise, leaving a small platform in front and rear.

The method and place of carrying the spare wheel and pole to be the same as in the present model, and the caisson body to be provided with a simple brake lever.

The board recommends that the gun carriage and caisson for the heavier field gun, as well as their equipment, be similar to those for the lighter, with such modifications as the greater weight and dimension of the gun and projectile require.

THE BATTERY WAGON.

That the wheels of the battery wagon be interchangeable with all other wheels in the battery, and the limber be similar to all other limbers; and that the chest only differ in its internal arrangement, being provided with drawers for the safe and convenient carriage of tools and stores.

That the frame of the battery wagon be the same as that of the caisson, except that the rails be longer to the rear. That the box be made of iron or steel, and rectangular in shape, with a sloping roof, and to have a longitudinal strip along the roof, to which the two sloping lids can be hinged. The box to be 80 inches long and 40 inches wide, 20 inches high at the sides, and 25 inches high at the center. There should be a till 12 inches wide across the front end of the box; the bottom of the till 12 inches above the bottom of the box, and the sides of the till to be carried up to the roof. There should be a longitudinal partition dividing the box, but not the till, into two halves.

The outside of the box to have six 1½-inch rings on each side and three on each end. The rings to be of three-eighths iron and to be fastened about 3 inches below the top of the sides and ends, as shown in plates 2 and 3.

The Board recommends below what the contents of the forge and b
should be, and omits the details for their stowage and arrangement, wh
with the strength and dimensions of the parts of the carriages, they bel
be determined by the constructors.

It is recommended, however, that both the battery wagon and forge
with a simple lever brake, as suggested for the caisson, and that all carr
nished with pole-props and painted a light green olive color, trimmed wit
poles single-trees, and the handles of all tools and implements to be oile
natural color of the wood.

That part of the pole which comes into contact with the leg-guard
driver to be protected from wear by copper or other material.

EQUIPMENT OF CARRIAGES.

The gun, 1 breech and vent cover, 1 tompion.

GUN CARRIAGE.

The tools, implements, and equipments required for the mechanism a
the gun.

LIMBER OF PIECE.

One paulin, 12 by 15 feet; 1 prolonge, to be wound on hooks placed in rea
plane through the hooks to be horizontal; 1 grease box, to hold 3 pounds,
under the limber; 3 watering buckets, to be of leather, copper riveted,
means of snap hooks under the foot-boards and as high from the ground
2 axes, felling.

LIMBER OF CAISSON.

One paulin, 12 by 15 feet; 1 3-inch rope, 50 feet in length, with 6-inch
ends, to be carried as prescribed for the prolonge; one 8-ounce gradu
measure; 3 water buckets, to be carried as prescribed for limber of piece;
as per piece limber; 2 axes, felling.

CAISSON BODY.

1 spare wheel.
4 spades.
1 single-tree.
1 spare pole,
1 mattock.
1 wheel trace,

TOOLS AND STORES TO BE CARRIED IN FORGE.

Blacksmith's tools.

1	anvil, 100 pounds.	
1	anvil-block.	
4	aprons, smith's.	
1	brush, horse-tail.	
1	bucket forge.	
2	boxes shoeing, leather.	
1	calipers, smith's.	
2	chisels for hot iron, handled, assorted.	
2	chisels for cold iron, handled, assorted.	
2	chisels, cold hand.	
1	compass, common.	
1	oil dropper, pint, brass.	
4	dies and taps	size suitable for new iron carriage.
1	die-stock for above	
6	drills, assorted, for brace, hand.	
12	files, smith's, assorted.	
3	file-handles, patent.	
1	fuller, handled.	
1	hammer, hand, handled.	
1	hammer, riveting, handled.	
4	hammers, shoeing, handled.	
1	hammer, sledge, handled, 9-pounds, steel faced.	
2	hardies.	
12	shoeing-knives.	
1	oil-stone, 2 pounds.	
3	pincers, shoeing.	
1	pincers, small.	
1	poker.	
1	pritchel, or clinching-iron.	
1	punch, round, hand.	
1	punch, square, hand.	
1	punch, fore, hand.	
1	punch, round, handled.	
1	punch, square, handled.	
1	punch, center, hand.	
1	punch, nail, hand.	
12	rasps, shoeing, 16-inch.	
1	screw-driver, hand.	
1	shovel, coal.	
1	shovel, smith's.	
8	wedges, bottom and top, 1 set each.	
1	split broom.	
1	square, steel.	
3	tongs, smiths'.	
2	vises, hand, small and large.	
1	vise, on forge.	
1	wrench, monkey, patent.	
1	wrench, tap.	

250	pounds coal, bituminous.
2	chains, Nos. 1 and 2——feet.
250	caulks, horse shoe.
500	horseshoes, Burden.
1	oil, sperm, quart can.
80	nails, Globe, pounds, Nos. 7, 8, and 9.
	Nuts and bolts and washers; assorted and
25	iron, bar, flat, assorted, pounds.
25	iron, round, assorted, pounds.
25	iron, bar, square, assorted, pounds.
50	links, cold, shut, Nos. 3 and 5.
6	linchpins and washers.
5	steel, blister, pounds.
5	steel, cast, pounds.
25	hooks (double S), Nos. 1 and 2.
10	tire-bolts.

100	needles, assorted.
5	needles, collar.
24	needles, sail.
1	nippers, cutting.
1	oil-stone.
1	palm, sailor's.
1	pincers, pair.
1	pliers, pair.
1	pricking carriage and 3 wheels, Nos. 8, 10, and 12.
1	punch, hand.
1	punch, spring, revolving.
1	rivet, set.
1	rule, 2-foot.
1	sandstone.
2	scissors, pairs.
1	screw-driver, 3-inch.
1	shears, pair, 6-inch blade.
4	thimbles.

Stores.

1	beeswax, pound.
1	blackwax, pound.
1	bolts, halter, dozen.
2	bristles, ounces.
2	buckles, dozen, iron-roller, assorted.
2	buckles, Carnes's patent, dozen, assorted.
1	buckles, bar, dozen, assorted.
1	buckles, girth, dozen.
2	leather, bridle, sides.
75	leather, harness, pounds.
2	rings, dozen.
3	rivets and burs, copper, assorted, pounds.
2	staples, dozen.
3	tacks, iron, papers of.
2	tacks, copper, papers of.
2½	thread, patent, shoe, pounds.
3	thread, shoe, pounds.

NOTE 2.—That in addition to above tools and stores the Board requ
Ordnance Department add such other tools and stores as may be require
pair of the iron carriage furnished.

NOTE 3.—The sizes of horseshoes required should be designated in the
but in cases when this is not done the following should be the propor
cent. of No. 3, 55 per cent. of No. 4, and 5 per cent. of No. 5.

1 bevel-square.
1 50-foot tape measure.
1 brace, hand, metal, patent.
24 bits for brace, hand, assorted.
3 brace extensions for above, 6, 12, and 15 inch.
1 chalk-line on spool.
2 chalk, pounds.
4 chisels, handled, firmer, ¾, 1, 1¼, and 1½ inch.
5 chisels, handled, framing, ½, ¾, 1, 1½, and 2 inch.
1 compass, spring.
1 drawing knife.
12 files, hand-saw, 4½-inch.
2 files, wood, flat, 10-inch.
2 files, wood, half-round, 10-inch.
2 files for cross-cut saws.
1 gauge, carpenter.
6 gimlets, assorted.
3 gouges, firmer, handled, ¾, 1, and 1½ inch.
2 gouges, framing, handled, 1 and 1½ inch.
1 grindstone, 14 by 4 inches.
Arbor, crank, and stand for grindstones; the frame to be made so as to take apart and pack flat.
1 hammer, claw, handled.
1 hatchet, claw, handled.
1 mallet, carpenter.
1 oil-stone, 1½-pound.
1 oil-dropper, pint, brass.
1 pincers, small.
1 plane, fore, 2½-inch, double irons.
1 plane, jack, 2½-inch, double irons.
1 plane, smoothing.
2 plane-irons, 2¼-inch.
1 rule, 2-foot, four-fold.
1 rasp, wood.
1 saw-frame, complete.
6 saw-frame blades, assorted.
1 saw, hand, cross-cut, 26-inch.
1 saw, tenon, 14-inch.
1 saw, cross-cut, handled, 5-inch.
1 saw set, patent.
2 screw-drivers, 6 and 12 inch.
1 screw-driver for brace hand.
1 square, trying, 7½-inch.
1 spoke-shave.
3 screws, gross, assorted.
1 vice bench, wood, complete (iron screw).

MISCELLANEOUS STORES.

6 gas-checks for gun.
6 lanyards.
6 lanterns, hurricane, kerosene.
5 oil, kerosene, gallons.
75 grease, wheel, pounds.
25 nails, 4, 6, 8, 10, p. pound.
6 spokes.
1 lifting-jack (lights).
2 reaping hooks.
6 side lines.
2 wheel traces.
2 lead traces.
20 whips.
6 collars.
16 hair cinches.
6 bridles.
12 halters.
25 hame straps.
12 halter chains.
20 nose bags.
6 sash cord pieces.
5 marline, pounds.

1	elevating screw.
1	hames, pair.
2	pole pads.
1	leg guard.
2	tompions.
2	single-trees.
1	sight, telescopic.
1	sight, ordinary.
1	sight, muzzle.
1	odometer.
5	cotton waste, pounds.
1	ordnance manual.
5	sets knives, forks, spoons, meat ration cans and haversacks and tin cups.
1	pole yoke.
6	priming wires.
3	gunner's gimlets.
3	vent punches.
4	rammer heads.
4	sponge heads.
6	sponges.
6	sponge covers.
25	curry-combs.
6	horse covers, canvas.
25	brushes.
10	spurs and straps.
20	surcingles.
25	blankets.
5	paint, olive, mixed in oil, pounds, to be packed in 1-pound cans with screw tops.
2	paint, black, pounds.
2	oil, linseed, raw, gallons.
¼	oil, linseed, boiled, gallons.
1	turpentine, spirits of gallon.
6	brushes, paint, assorted.
2	sash tools, assorted.
5	sand paper, assorted, quires.
3	cloth, emery, assorted, quires.
5	cloth, crocus, quires.
25	tripoli, papers.
2	rotten stone, pound.
2	oil, sperm, gallons.
4	oil, neat's-foot, gallons.
10	oil, harness, Collins, prepared, gallons.
20	soap, castile, pounds.
10	sponge, pounds.
2	logwood, extract, pounds.
2	lampblack, pounds.
50	grease, wheel, pounds, to be issued in 2-pound-cans with screw tops.
1	gauge for fitting bits to horses, to consist of a graduated mouth-piece and one adjustable cheek-piece.

In a report submitted by me in accordance with instructions of the Chief of Ordnance, United States Army, the following relates to the construction of these carriages:

CAISSON.

Wrought iron should be employed for the caisson body, for the same reason as above, and homogeneous steel might be used for the box. The lid of chest should be in two parts, hinged along middle line to a longitudinal piece; this will be possible since the small platform desired in rear of chest will remove the spare wheel from the lid; a brake, operated by a screw with handle in rear, would be attached.

If this chest is to be arranged for the transportation of cannoneers, since the half lids must slope outward, a seat resting on iron brackets would be placed at each end of each half lid, and there could also be in front a screw or lever to operate the brake.

The projectiles will be placed upon end, separated by partitions of galvanized iron, the cartridges in copper trays to slide over the partitions, exposing the projectiles.

BATTERY WAGON.

The frame to be of wrought iron, and the box of sheet-iron or homogeneous steel, stiffened by pieces of channel iron; sliding trays of metal or wood, with cover, will be used for tools and small stores.

FORGE.

The frame and box will be of the same general construction as those of the battery wagon. A rotary fan to be used as proposed by Colonel Laidley; the tools and stores to be arranged in compartments in a manner that it is thought will be more simple and cheaper than in the cavalry forge, the fastenings to be reduced and simplified, and the cost of certain parts to be reduced.

WAGON FOR AMMUNITION.

As the ammunition in this wagon is to be carried in packing boxes, the ends of wagon should be removable; the two spare wheels called for can it is thought, be placed horizontally on frames resting on the lid; if desirable, the frames and lid can be removed for loading the wagon.

GENERAL CONSTRUCTION OF CARRIAGES.

The iron used in the frames of the limber, caisson, battery wagon, and forge will be of the same form for similar parts.

I propose to employ H iron for the stocks, T or L for the rails, L iron for braces and cross-pieces, and T or L iron for splinter bars.

For these it is believed that mercantile forms can be obtained and the samples be constructed; should it hereafter be found that steel would be more advantageous, the forms necessary would have to be made specially for the purpose.

No complete plan for any one carriage can be made till the work is undertaken and it is seen what dimensions or shapes cannot be obtained, and what difficulties in working the forms may be encountered; and for the same reason no estimate of cost can be made with any accuracy; similar work done at this arsenal has been taken as the main guide in preparing the estimate now submitted.

Upon the preceding report the indorsement of the Chief of Ordnance was to the effect that the general recommendations as to construction should be carried out, care being taken to so arrange the longitudinal joint in lid of caisson chest that water could not enter.

In the manufacture of these carriages endeavor was made to embrace all the features and conditions desired by the Light Artillery Board, all details of construction having to be determined by me. Without detailed plans and with only such drawings as might be prepared from day to day, the work progressed under many difficulties, and consequently very slowly.

There have been produced experimental carriages, which, though far from perfect, may serve to lead the way to better and finally satisfactory constructions.

Later experience in the manufacture of metal carriages has indicated how defects known to exist in the earlier ones can be remedied.

  1 lever, iron.
  1 crank-bar, low steel.
  2 lugs, iron.
  2 cranks, iron.
  2 connecting rods, low steel.
  1 brake-bar, compound, low steel.
  2 shoes, iron, faced with leather.
  2 brackets, iron, to support brake-bar.
4 corner irons, iron.
1 spare pole-ring, iron.
1 spare pole key-plate and key, iron.
2 wheels, "Archibald."
6 bolts, low steel, for axle-straps.
3 bolts, low steel, for spare wheel-axle.
4 bolts, low steel, for attaching chest.

The parts of the frame are united in the same manner as i bers, and the axle is attached by bolts.

The brake is brought into action by raising the lever. This i crank-bar, which is supported by the lugs, riveted to the a raises the cranks, and by the connecting-rods, draws back t bar pressing the shoes against the wheels.

AMMUNITION-CHEST.

The caisson carries but one chest. The bottom, sides, ends tition of this are of steel 0.12 inch thick, whilst the lid is inch thick.

The general construction and the filling is the same as in t chest of Pattern No. 2.

On the right side of the chest is riveted a ratchet-plate fo ice of the brake-lever.

The chest was made on dimensions determined for a simila ment of the projectiles, but one which required a greater a fore spaces were left between the holders and the sides of

1 single-tree, attached to front of chest by 2 spring-catches and to foot-board by 1 hook.
2 spades, secured to rear of chest by sockets and spring-clasps.
2 spades, on rear platform.
1 mattock and 1 pick on rear platform, one point of each entering sockets on right side of chest. The handles are strapped with the spades to the platform.
3 shovels, with long handles, attached to the left side by metal straps extending from the chest.

WEIGHT.

	Pounds.
Caisson, complete with chest, spare parts, and tools	1,632
Body, with 2 wheels	938
Chest, with filling	412
Filling	153
Wheel	200

BATTERY WAGON.

(Plate IV.)

PRINCIPAL PARTS.

The principal parts of the battery wagon are—

1 axle, steel, 3 by 2½ inches.
1 stock, iron, channel 6 by 2.25 inches by 0.28 inches.
2 side rails, iron, angle 4 by 3 inches by 0.375 inches.
2 cross-plates, Bessemer steel, ¼-inch thick.
1 lunette, iron, forged.
3 axle-straps, iron.
1 brake, composed of—
    1 crank-handle, iron.
    1 screw, iron.
    1 nut, bronze.
    1 stirrup, iron.
    1 connecting-rod, long, low steel.
    1 link, iron.
    2 connecting-rods, short, low steel, each in two parts with coupling.
    1 brake-bar, compound, low steel.
    2 shoes, wood.
2 wheels, "Archibald."
6 bolts for axle-straps, low steel.
6 bolts for attaching chest, low steel.
1 chest, sheet steel, 0.109 inch thick, except the lids, which are 0.083 inch.

CONSTRUCTION.

The parts are united in the same manner as in the other metal carriages.

The wheels of all the carriages are of one pattern and are interchangeable.

All parts of the chest are of metal. It is divided longitudinally by a partition extending from bottom to top, and in each half are two cross-partitions about half the height of the sides.

A till is formed in the upper front part of the chest.

The rings on the exterior are for lashing supplies, as forage, that it may be desired to transport without the chest.

The cover is formed of two lids, hinged to a ridge-piece. The packing box extends along the outside of the sides and ends and on the under side of the ridge-piece. To press the lid against the rubber packing two of Lieutenant Gordon's fastenings are used and one operated by an eccentric turnbuckle applied for trial.

In the body of the chest are to be packed the supplies and the spare parts, the tools being placed in the till and in the chest of the limber. The long cross-cut saw is carried against the main partition, held by three spring-brackets.

AMMUNITION WAGON.

(Plate V.)

The conditions prescribed by the Light Artillery Board for this wagon admitted of but one general plan for its construction.

No other place could be found for the spare wheels, but above the lid, and they had to be so arranged as not to interfere with the removal of the top or ends of the body. The parts may have been made stronger and heavier than necessary, otherwise they appear to perform well the service required of them.

The running gear is that of the regulation wagon used by the United States Quartermaster's Department.

The length and height of the wooden body was determined for the load it was assumed should be carried, taken at 28 boxes, or 280 rounds of ammunition for 3.2 inch rifle, about 5,200 pounds, including boxes.

The lid is in two parts, of wood covered with canvas, painted.

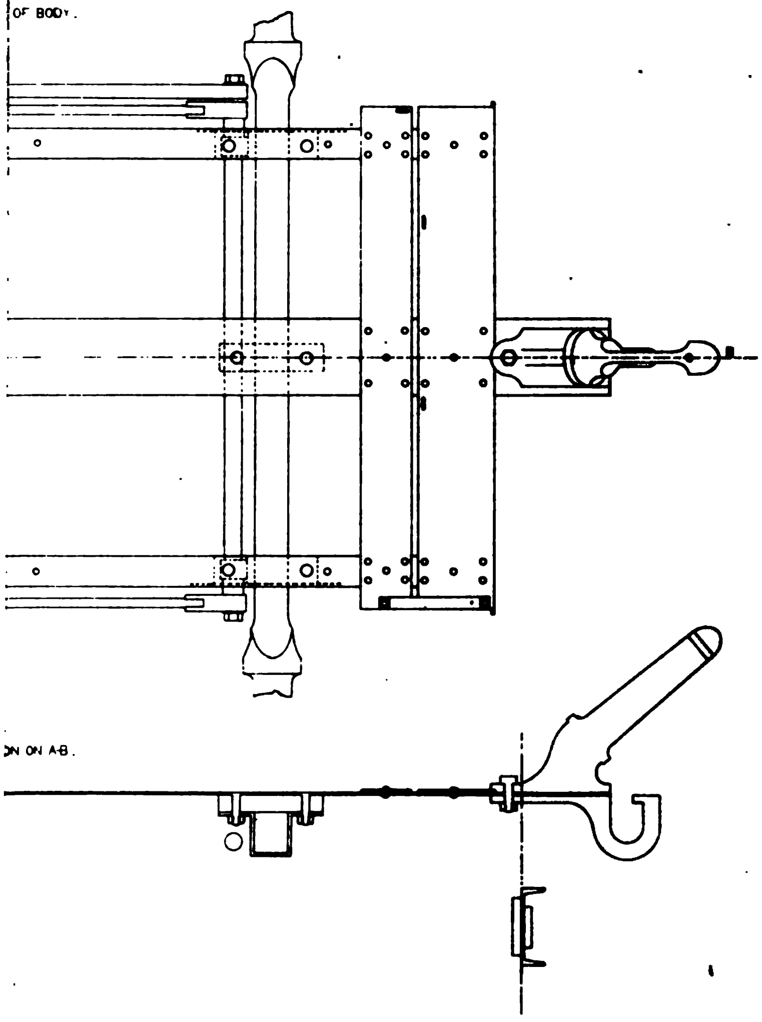
The "boards" that close the ends are alike.

The construction of the body in all its details is shown so fully and clearly in the drawings, that no further explanation appears necessary.

This wagon, like all the experimental artillery carriages, is painted, as recommended by the Light Artillery Board, green, the color being lighter than the olive generally used on artillery carriages, and supposed to approach nearer to the green foliage of trees.

A. MORDECAI,
Lieutenant-Colonel of Ordnance, Commanding.

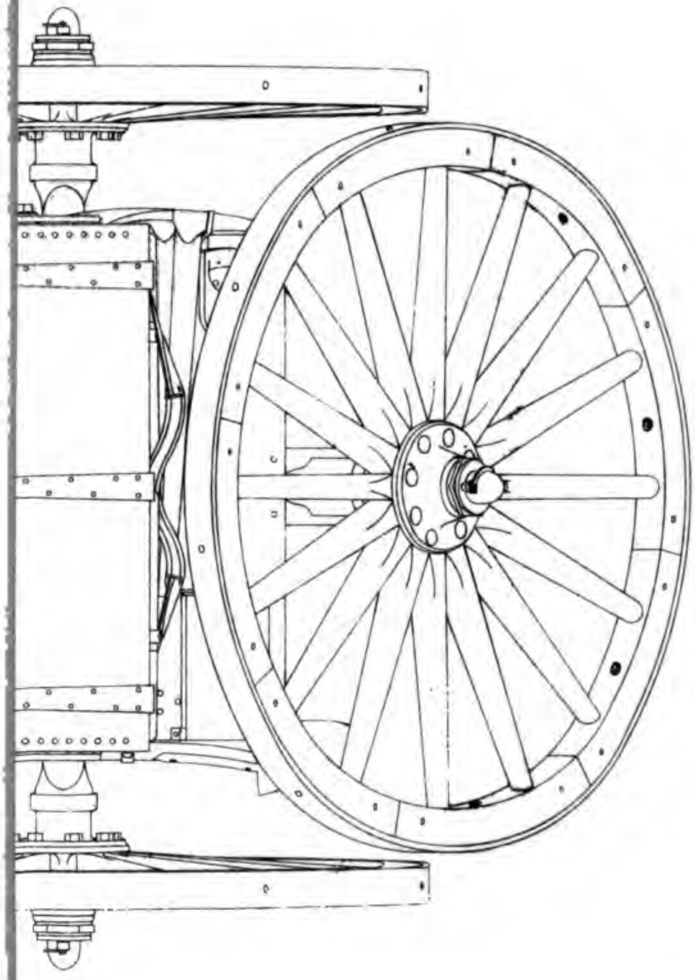
Plate I.



A. Mordecai
Lt. Col. of Ordnance,
Commanding

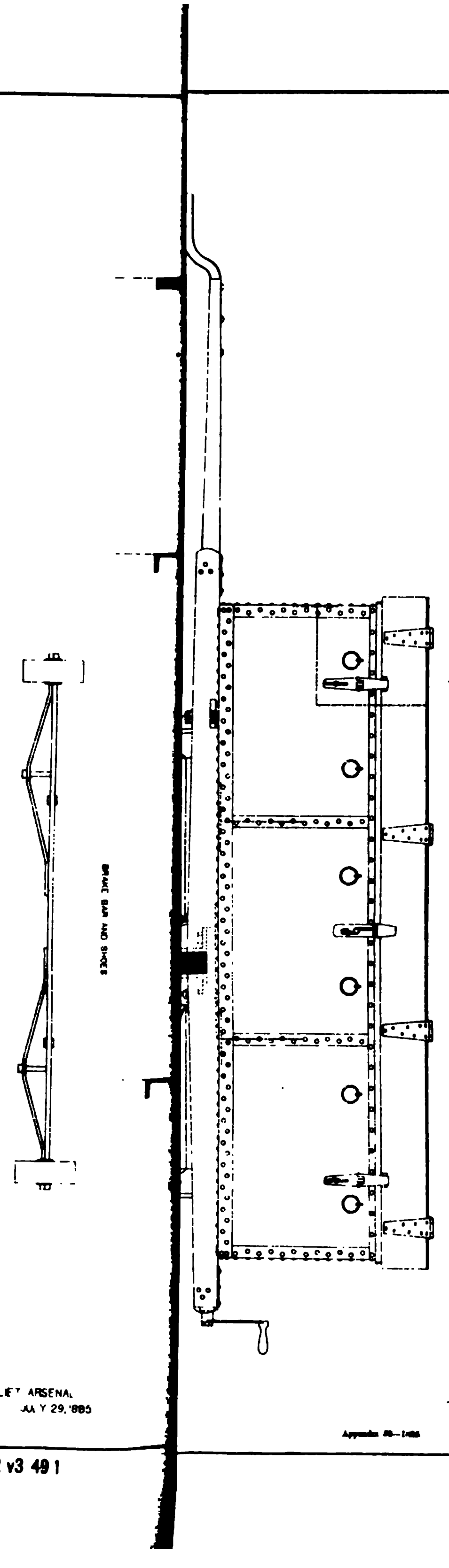
Appendix [illegible]

H Ex1 pt2 v3



A Mordecai
Lt Col of Ordnance
Commanding

Plate IV.



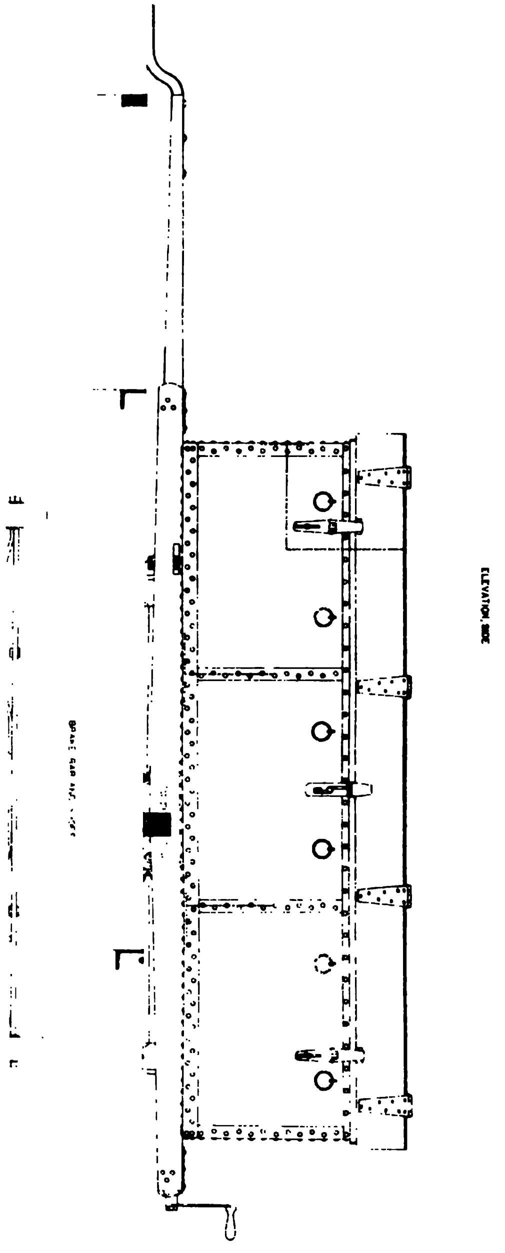
WATERVLIET ARSENAL
JULY 29, 1885

Lt. Col. of Ordnance
Commanding

Appendix [illegible]—1885

H Ex1 pt2 v3 49 1

Plate IV.

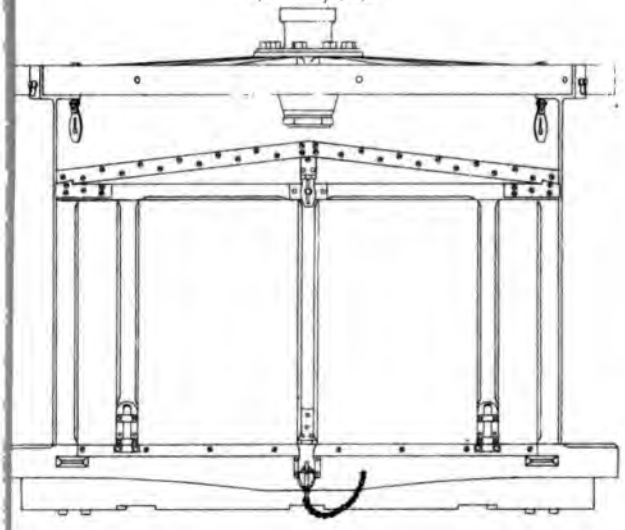


SENAL
879 885

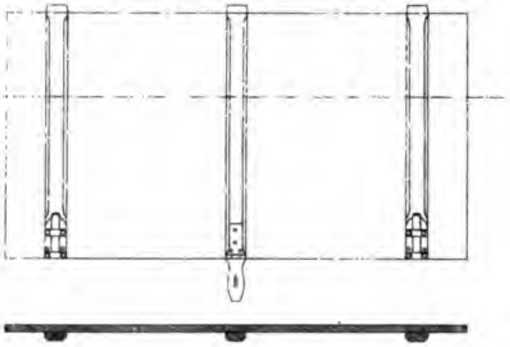
Appendix [illegible]

Lt. Col. of Ordnance
Commanding

END ELEVATION



END BOARD



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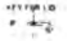


Appendix 38—1883.

A Mordecai
Lt Col of Ordnance
Commanding

APPENDIX 59.

REPORT ON ARTILLERY MACHINES FABRICATED AT WATERVLIET ARSENAL.

(1 plate.)

WATERVLIET ARSENAL, N. Y.

HAND-SLING CART.

My personal experience during the late war, and since, proved that the hand-sling cart was not sufficiently strong to withstand the weights it was frequently properly called upon to carry; therefore, when required twice in the past three years to fabricate a sling-cart for the use of the U. S. Light-House Service, a stronger construction was adopted.

The most serious injuries to the ordnance cart were the bending of the axle about the center, and the breaking of the axle-arms at the shoulder.

The changes made are as follows, viz:

(1) The axle is increased to a uniform thickness of 2.625 inches, and depth of 3.8 inches, except in rear of shoulder-washers, where it is 3.5 inches.

(2) The axle-arms are joined to the body by curved surfaces, and are increased in diameter for a length of 0.9 inch, where a second curved surface is used to unite with the principal length of arm. This form was adopted since it was desired to use wheels on hand of different patterns, which would not admit of the hub being reamed throughout its length.

For new constructions, the hub should be enlarged and the axle-arms increased and given a uniform taper.

(3) The form of the hook is somewhat changed and its dimensions are increased.

(4) The cross-section of the pole is enlarged and chambers are omitted.

(5) The pole-straps are increased in thickness and length, and extended beyond the point of attachment of the braces.

(6) The diameter of the braces is increased, also that of the bolt connecting them with the pole.

PINCH-BAR, &C.

Pinch-bars, for use in mechanical maneuvers at the forts, have been made by me heavier than those formerly fabricated at this arsenal, in order that they might conform to the requirements of Tidball's Manual. About 8 inches at the lower end of the bar is steel; the remainder is stiff iron.

The sling-chain is that prescribed in Tidball's Manual, page 200.

The holdfast-pin and the sluing-chock, shown in plate, were made to fill requisitions for such articles. The latter is referred to in Tidball's Manual, page 270.

The pin is entirely of iron; would be improved if made partly or entirely of steel.

The chock is of oak with claws of iron.

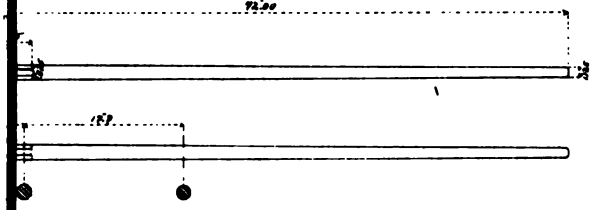
The dimensions of all of the above machines are given on the drawings.

A. MORDECAI,
Lieutenant-Colonel of Ordnance, Commanding.

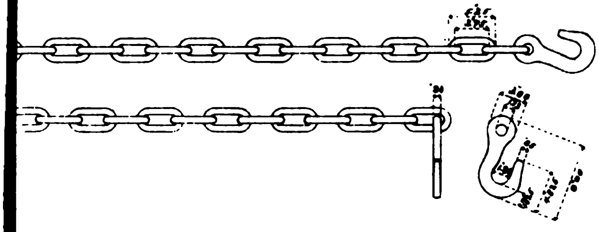
WATERVLIET ARSENAL, N. Y., 1885.

Plate I.

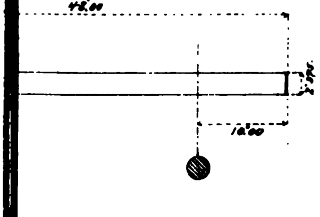
PINCH BAR.



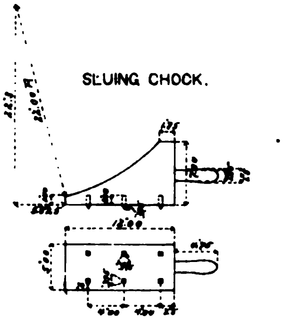
SLING CHAIN.



LDFAST PIN.



SLUING CHOCK.



Appendix 59—1865.

A Mordecai
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Commanding

APPENDIX 60.

REPORT OF THE CONSTRUCTION OF METAL FIELD CARRIAGE AND LIMBER FOR GATLING GUN, CALIBER 0.45 INCH, PATTERN 1884, WITH ECCLES FEED, AT WATERVLIET ARSENAL.

(6 plates.)

WATERVLIET ARSENAL, 1885.

The general pattern of the gun carriage and limber is shown in Plate I.

As the number of carriages ordered to be made precluded the idea of an experimental construction, care was to avoid the adoption of features that had not been tested in other metal carriages, or in regard to the utility of which much doubt could be raised.

In designing this work valuable assistance was received from Lieut. W. B. Gordon, Ordnance Department.

The limber, it is thought, will be found to fulfill the requirements of the service. The advisability of some of the features in the gun carriage can be determined only by trial. No provision was made for filling the Eccles feed-cylinders.

PRINCIPAL PARTS.

GUN CARRIAGE.

(Plates IV and V.)

1 axle-steel, 2.5 by 2.25 inches.
2 trail-plates, mild steel, 0.2 inch thick.
2 angle irons, iron 1.25 by 1.25 inches.
2 trail-cheeks reinforces, mild steel, 0.2 inch thick.
1 axle block, bronze.
1 axle-strap, iron, forged.
1 lunette, iron, forged.
1 lunette-plate, with lug, iron, forged.
5 transoms, mild steel, 0.2 inch thick.
2 braces, iron.
1 trail-seat, steel homogeneous, 0.1 inch thick.
1 trail-handspike, 1-inch gas-pipe.
2 trail-handles, iron.
1 swivel mounting, composed of—
    1 gun-support, bronze.
    2 cap-squares, bronze.
    2 cap-square keys, bronze.
    1 traverse-binder, iron.
    1 elevating-arc, low steel.
    1 arc-binder, low steel, handle bronze.

1 axle, steel, 2.5 by 2.25 inches.
2 hounds, iron, angle, 3 by 2 inches.
1 fork, iron, of 2 angle-bars, 3 by 2 inches.
1 splinter-bar, iron, angle, 3 by 2 inches.
2 foot-plates, steel, Bessemer, 0.165 inch thick.
1 pintle-hook, iron, forged.
1 pintle-hook key, iron.
1 pole prop, 1-inch gas-pipe.
3 axle-straps, flange iron, 0.375 inch thick.
1 fork-strap, flange iron, 0.375 inch thick, with eye, iron.
1 front fork-strap, iron, 0.25 inch thick.
1 evener plate and pin, iron, forged, 0.375 inch thick.
1 evener-pin brace, iron.
2 corner irons, iron, 0.375 inch thick.
1 pole, wood
1 pole-yoke, iron.
1 pole-key, iron.
1 evener, wood, 2 end bands, iron.
2 single-trees, wood, 2 middle bands and 4 end bands and ho
4 foot-plate brackets, iron.
Clasps, steel.
Bolts, low steel.
Rivets, iron.
2 wheels, Archibald.

LIMBER, AMMUNITION CHEST.

(Plate III.)

1 bottom, steel, Bessemer, 0.1 inch thick.
2 sides, steel, Bessemer, 0.1 inch thick.
2 ends, steel, Bessemer, 0.1 inch thick.
1 top, steel, homogeneous, 0.1 inch thick.
2 partitions, steel, Bessemer, 0.1 inch thick.
1 subpartition, steel, Bessemer, 0.083 inch th k.

2 handles, iron.
2 clasps, iron.
2 turnbuckles, low steel.
Linings to protect feed-cylinders, wood.
4 bolts, low-steel, to attach chest to limber-body.
Rivets, iron.
1 padlock, brass.

CONSTRUCTION.

CARRIAGE.

All the parts that compose the stock proper and all the minor parts attached to it are united by rivets. In addition, there are 4 bolts that assist in securing the trail-plates to the axle-block at points where rivets cannot be inserted.

Upon the completion of the first carriage a want of stiffness was found to exist at the junction of the trail-plate and axle-block, and to overcome this the trail-cheek reinforce was added.

The axle-strap, by which the stock is attached to the axle, is secured by 4 bolts threaded into the axle-block.

Six bolts through each bottom plate secure the chest to the axle. Two of these bolts pass also through the braces. The axle had to be planed where enveloped by the axle-block and the chests to insure a true bearing.

Four of the carriages were fitted with an experimental forked trail handspike, shown on Plate V.

In the axle-chests the back, bottom, and front are of one sheet, bent cold, six times parallel to the axle, and four times perpendicular to it, the latter to form corner angles to which the ends are riveted. Angle pieces riveted to the ends extend under the bottom, but constitute bands only around three sides of the axle. The upper band is in rear, bent into the lower member of the hinge.

The lid is bent double about three edges, and from the fourth is formed the upper member of the hinge. In these chests rivets only are used.

Each chest contains two feed-cylinders, protected by the wooden fillings. In the blocks over the axle and between the feeds are placed tools for the service of the gun and carriage.

In the right chest are—

1 crank-handle for gun.
1 drift.
1 lock screw-driver.
1 hand screw-driver.
1 T screw-driver.
1 pin-wrench.
1 sight, right.

In the left chest are—

1 cam-extractor.
1 riveting-hammer.
1 oil-can.
1 screw-wrench.
1 sight, left.

On the stock are carried, secured by stops and clasps—

1 oscillating lever.
1 wiping-rod.

LIMBER.

BODY.

The frame of the body is put together and secured to the axle entirely by rivets. The only bolts used are four, that attach the pintle-hook to the fork.

Where the hounds and fork rest upon the axle the web is cut away to the flange. To compensate for this the axle-straps are forged with webs, the vertical angle of junction with the strap being solid. These straps, riveted to both flange and web of the angle-irons, restore the strength lost by cutting. The same construction is adopted in the fork-strap.

On some of the limbers the evener-pin is riveted in the plate; on others the two are forged in one piece. The latter plan was considered preferable.

Ten limbers were made with eveners (Plate I), and correspond to details in Plate VI. The other ten had two single-trees, each attached to draught-hooks as in Plate II. The difference in the parts can be readily understood from the drawings.

AMMUNITION CHEST.

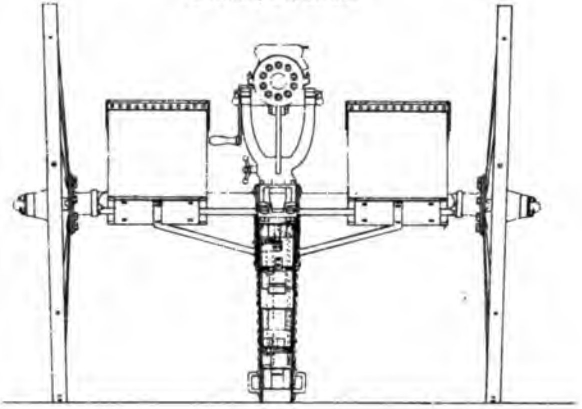
As the chest opens at the top and as all the ammunition to be carried is water-proof in itself, no packing-box and rubber packing are needed. This simplifies much the construction of the chest.

No bolts whatever are used.

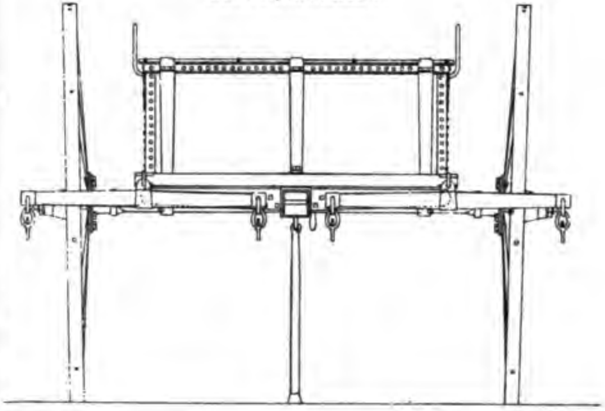
The capacity of the chest as filled is: right compartment, 132 packages of 20 cartridges each; left compartment, 132 packages of 20 cartridges each; center compartment, 4 feed-cylinders of 104 cartridges each; front center compartment, 38 packages of 20 cartridges each; making in all 6,444 rounds of ammunition.

Provision is made for four feed-cylinders in this chest, as it was thought the four on the carriage would probably be found insufficient. If this be not desired the wooden linings can be removed, and the space thus left will contain 165 packages of 20 cartridges each, which would

ELEVATION, REAR, CARRIAGE



ELEVATION, FRONT, LIMBER.



A Mordecai
Lt Col. of Ordnance,
Commanding

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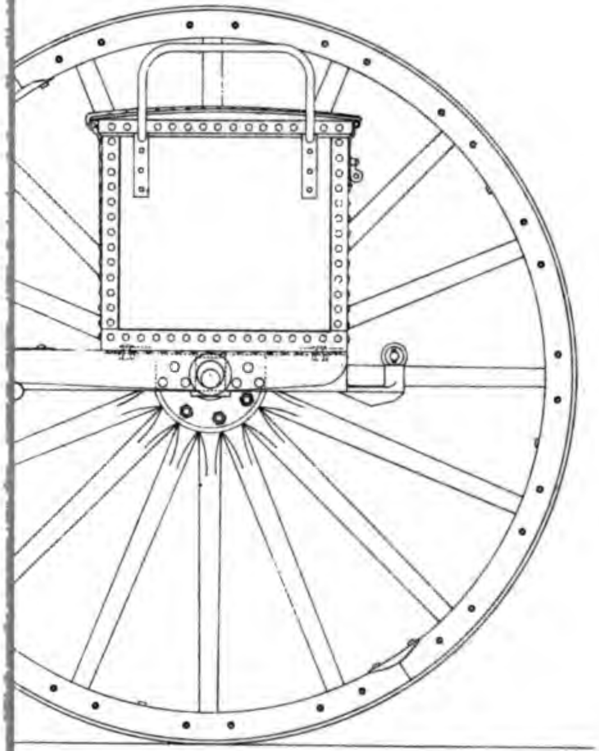

ELEVATION, SIDE.

A. Mordecai
Lt. Col. of Ordnance,
Commanding

Plate III.

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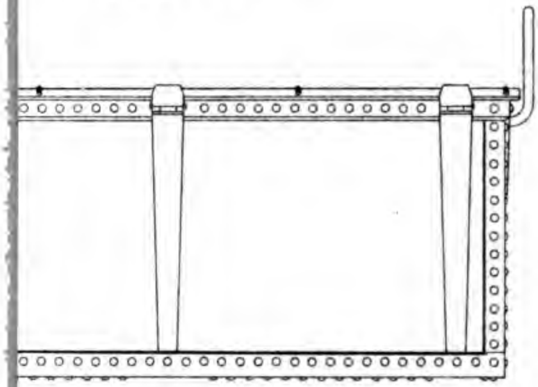
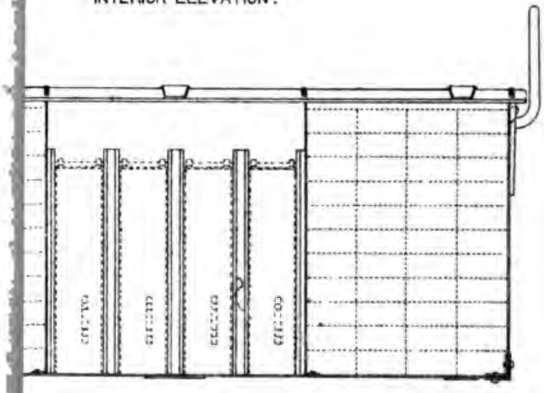
REAR ELEVATION.



INTERIOR ELEVATION.

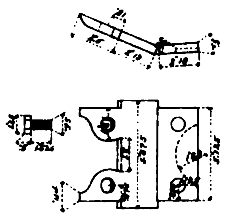


A Mordecai
Lt. Col. of Ordnance.
Commanding

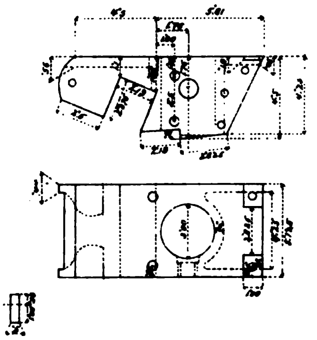
Appendix 60—1885.

Plate IV

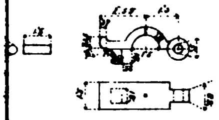
UNDER STRAP.



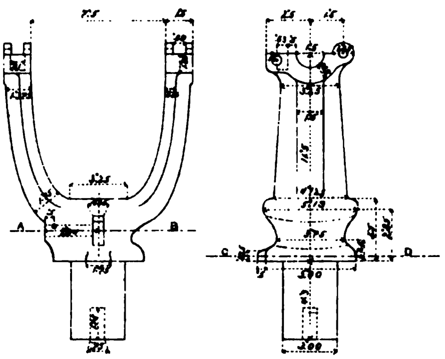
AXLE BLOCK.



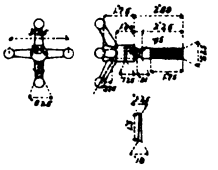
CAP SQUARE.



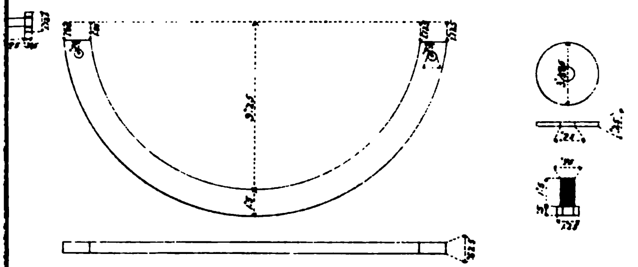
GUN SUPPORT.



ARC STOP.



ELEVATING ARC.



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A Mordecai
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Commanding.

Appendix 60—1885.

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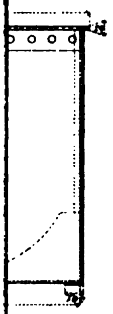
Plate V.

CARRIAGE CHEST.

ON.



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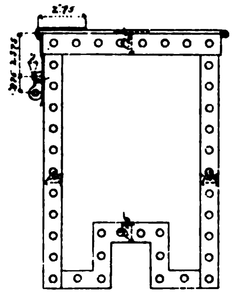
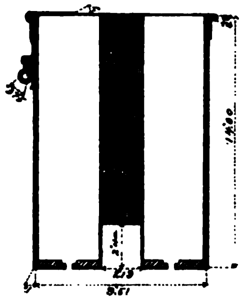
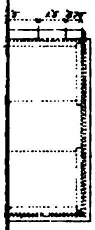
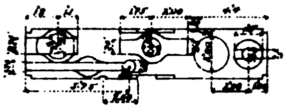


SECTION ON A-B.

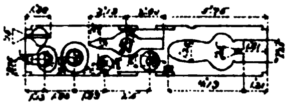




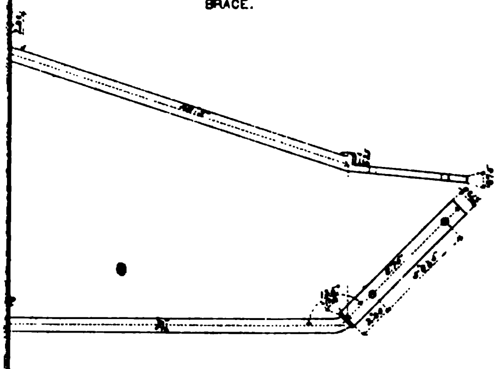
TOOL BLOCK, RIGHT CHEST.



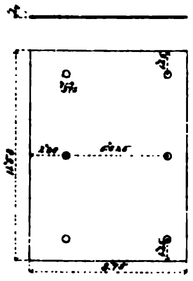
TOOL BLOCK, LEFT CHEST.

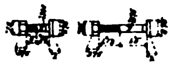


BRACE.



BOTTOM PLATE,
CARRIAGE CHEST.





WA

A Mordecai
Lt. Col. of Ordnance
Commandi

Appendix 60—1865.

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Provision is made for four feed-cylinders in this chest, thought the four on the carriage would probably be found If this be not desired the wooden linings can be removed, an thus left will contain 165 packages of 20 cartridges each, w allow the chest to carry 9,340 rounds instead of 6,444.

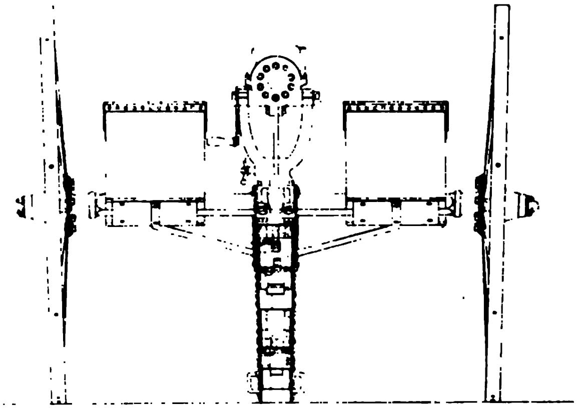
WEIGHT.

Gun-carriage, with chests and tools, without feed-cylinders ....
Limber and chest, pattern with evener ....
Limber and chest, pattern without evener ....
Ammunition chest ....
One wheel ....
Gun ....
One feed-cylinder ....

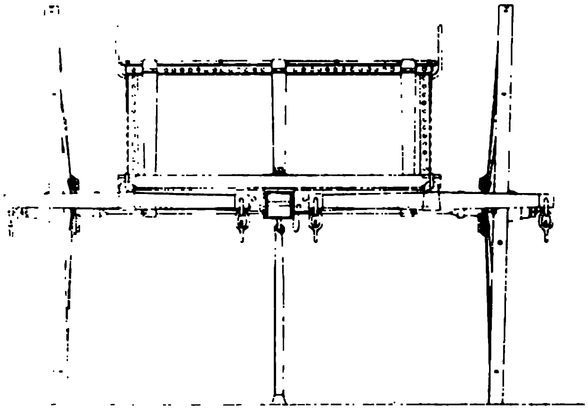
A. MORDE
Lieutenant-Colonel of Ordnance, Com

Plate I.

ELEVATION, REAR, CARRIAGE



ELEVATION, FRONT, LIMBER.



A Mordecai
Lt Col. of Ordnance
Commanding

Appendix 60—1883.

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APPENDIX 61.

SHOWING STATIONS AND DUTIES OF THE OFFICERS OF THE ORDNANCE DEPARTMENT ON OCTOBER 1, 1885.

Rank and name.	Duty.	Address.
BRIGADIER-GENERAL.		
Stephen V. Benét	Chief of Ordnance, and member of Fortification Board.	**Washington, D. C.**
COLONELS.		
1. J. McAllister, brevet	Commanding the Benicia Arsenal	**Benicia, Cal.**
2. S. Crispin, brevet	Commanding the Frankford Arsenal	**Philadelphia, Pa.**
3. T. G. Baylor, brevet	Commanding the New York Arsenal, president of the Ordnance Board, and president of the Board for Testing Rifled Cannon, &c.	**Governor's Island, New York City. Post-office box 1449.**
LIEUTENANT-COLONELS.		
1. J. M. Whittemore	On duty in the office of the Chief of Ordnance.	**Washington, D. C.**
2. A. R. Buffington	Commanding the National Armory	**Springfield, Mass.**
3. D. W. Flagler, brevet	Commanding the Rock Island Arsenal.	**Rock Island, Ill.**
4. A. Mordecai, brevet	Commanding the Watervliet Arsenal	**West Troy, N. Y.**
MAJORS.		
1. F. H. Parker, brevet	Commanding the Watertown Arsenal, and member of Board for Testing Rifled Cannon, &c.	**Watertown, Mass.**
2. J. P. Farley	Commanding the United States Powder Depot.	**Dover, N. J.**
3. L. S. Babbitt	Commanding the Fort Monroe Arsenal.	**Fort Monroe, Va.**
4. W. A. Marye	Commanding the Augusta Arsenal	**Augusta, Ga.**
5. I. Arnold, jr	Commanding the San Antonio Arsenal.	**San Antonio, Tex.**
6. C. Comly	Instructor of Ordnance and Gunnery, United States Military Academy.	**West Point, N. Y.**
7. J. R. McGinness, brevet	Commanding the Saint Louis Powder Depot.	**Jefferson Barracks, Mo.**
8. G. W. McKee, brevet	Member of the Ordnance Board, and member of Board for Testing Rifled Cannon, &c.	**Governor's Island, New York City. Post-office box 1449.**
9. F. H Phipps	Commanding the Kennebec Arsenal	**Augusta, Me.**
10. J. W. Reilly	Commanding the Allegheny Arsenal	**Pittsburgh, Pa.**
CAPTAINS.		
1. J. A. Kress, brevet major	Commanding the Indianapolis Arsenal	**Indianapolis, Ind.**
2. O. E. Michaelis, brevet	Assistant, Watervliet Arsenal	**West Troy, N. Y.**
3. C. E. Dutton	On duty under the Interior Department.	**Geological Survey, Washington, D. C.**
4. J. G. Butler	Assistant, Rock Island Arsenal	**Rock Island, Ill.**
5. C. Bryant	Assistant, Benicia Arsenal	**Benicia, Cal.**
6. A. L Varney	Assistant, Rock Island Arsenal	**Rock Island, Ill.**
7. J. C. Clifford	Assistant, Frankford Arsenal	**Philadelphia, Pa.**
8. J. E. Greer	Commanding the Fort Leavenworth Ordnance Depot, and chief ordnance officer Department of the Missouri.	**Fort Leavenworth, Kans.**
9. J. Pitman	Assistant, Watertown Arsenal	**Watertown, Mass.**
10. C. Shaler	Member of the Ordnance Board, and Member of Board for Testing Rifled Cannon, &c.	**Governor's Island, New York City. Post-office box 1449.**
11. H. Metcalfe	Assistant, Watervliet Arsenal	**West Troy, N. Y.**
12. W. S. Starring	Assistant, National Armory	**Springfield, Mass.**
13. C. S. Smith	Principal assistant in the Ordnance Bureau, and member of Fortification Board.	**Washington, D. C.**

	ordnance officer Department of Dakota.	
19. J. C. Ayres	Assistant, Benicia Arsenal	Benicia, Ca
20. M. W. Lyon	Assistant, Watertown Arsenal	Watertown
21. C. W. Whipple	Assistant to the Ordnance Board	Governor's York Ci box 1449.
22. A. H. Russell	Commanding the Vancouver Barracks ordnance depot, and chief ordnance officer Department of the Columbia.	Vancouver

FIRST LIEUTENANTS.

1. R. Birnie, jr	On foundry duty	Cold Sprin
2. I. MacNutt	Assistant, Frankford Arsenal	Philadelph
3. C. C. Morrison	Assistant, Rock Island Arsenal	Rock Islan
4. F. Baker	Assistant, Frankford Arsenal	Philadelph
5. O. B. Mitcham	Commanding the Cheyenne Ordnance Depot, and chief ordnance officer Department of the Platte	Cheyenne,
6. H. D. Borup	On foundry duty	Boston, M box 2232.
7. L. L. Bruff	Assistant instructor of ordnance and gunnery, U. S. Military Academy.	West Point
8. C. H. Clark	Assistant, National Armory	Springfield
9. W. M. Medcalfe	Assistant to the Ordnance Board	Governor's York Ci box 1449.
10. William Crozier	Assistant, Watertown Arsenal	Watertown
11. W. B. Gordon	Instructor of philosophy, U. S. Military Academy.	West Point
12. F. E. Hobbs	On foundry duty	Station G, Pa.
13. D. A. Howard	On foundry duty	Cold Sprin
14. Sidney E. Stuart	Instructor of philosophy, U. S. Military Academy.	West Point

ORDNANCE STOREKEEPERS.

Captains.

A. S. M. Morgan	On duty, Allegheny Arsenal.	Pittsburgh,
W. H. Rexford	On duty, Indianapolis Arsenal	Indianapoli
D. J. Young	On duty, Watervliet Arsenal	West Troy
M. J. Grealish	On duty, Augusta Arsenal	Augusta, G
V. McNally	On duty in the Office of the Chief of Ordnance.	Washingto

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